ARS National Research Program

NRP NO. 20350 Dairy production

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PREFACE

This document is one of the ARS National Research Programs (ARS-NRP's) or one of the ARS Special Research Programs (ARS-SRP's). These programs provide the basic plans for research in the Agricultural Research Service. The ARS-NRP's and the ARS-SRP's are a part of the ARS Management and Planning System (MAPS). The plans identify national research objectives, describe methods for achieving these objectives, and provide the accounting and reporting system by which these program areas are planned and managed.

Each of the ARS National Research Programs and Special Research Programs outlines a 10-year plan that describes current technology and new technology expected in the 10-year period. The plan includes approaches to research and benefits expected to result from new technology. The Special Research Programs facilitate research planning and management in those exceptional circumstances where special funds are involved or a different kind of research management is needed. They provide the same general type of information as the ARS-NRP's. Both types of research programs were prepared by the National Program Staff with the cooperation of Regional Staffs and Line Managers, Technical Advisors, Research Leaders, and other scientists.

These research plans will be used for a variety of purposes. They serve to link ARS research projects to major program areas involving several agencies within the USDA program structure. ARS-NRP's and ARS-SRP's identify important national problems and describe plans for achieving technological objectives. They provide justifications for current research activities and the basis for funds for future research. They serve as the basis for program reports and for the Agency's accounting system. They also improve the communication between scientists and management, between research managers and staff scientists, between ARS and other research organizations, and between USDA and other departments, the private sector, and Congress.

These documents are dynamic statements of ARS research plans and, as new knowledge is developed, they will be continually updated to reflect changes in objectives and research approaches.

ARS-NRP No: 20350
USDA Program No: 22-678

DAIRY PRODUCTION

Technological Objectives

III. 1. Improve efficiency of reproduction, lactation and other physiological processes

III. 2. Improve efficiency of feed utilization

III. 3. Improve genetic capacity for production

III. 4. Improve management practices and systems

III. 5. Improve efficiency of producing quality products

III. 6. Decrease losses due to diseases, pests and other hazards

Cross Reference by Technological Objective to Other NRP's

TO 1	NRP 20360	Beef Production
	20380	Sheep and Other Animal Production
TO 2	NRP 20100	Forage Crops Production
	20520	Processing Field Crops
	20360	Beef Production
	20380	Sheep and Other Animal Production
TO 3	NRP 20360	Beef Production
TO 4	NRP 20400	Livestock Structures and Equipment
	20420	Disease Control - Cattle
	20530	Technologies for Food and Feed Uses - Animal Products
	20790	Preventing Pollution of and Improving the Quality of Soil, Water and Air
TO 5	NRP 20530	Technologies for Food and Feed Uses - Animal Products
	20600	Marketing Livestock and Animal Products
TO 6	NRP 20420	Disease Control - Cattle
	20480	Livestock Insect Control
	20470	Toxicology of Chemicals and Poisonous Plants
	20460	Control of Foreign Animal Diseases

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DAIRY PRODUCTION

I INTRODUCTION

Milk and dairy products play a key role in nutrition. Individuals of both sexes and of all ages and races rely on dairy products for much of their nutrition. Dairy products provide 22 percent of the protein, 11 percent of the food energy, 12 percent of the fat, almost 76 percent of the calcium and 36 percent of the phosphorus for the American diet. Milk nutrients are of high quality and widely used. They are also a good buy. The real price of milk - the amount of work a consumer must do to buy it - was 15 percent less in 1974 than in 1960.

Farm sales of milk and of dairy beef together accounted for farm income of more than 11 billion dollars in 1974--second only to beef among agricultural commodities as a source of income. In nine States, milk is the leading source of agricultural income and in 39 States it is in the top five agricultural commodities.

Concern has been expressed about the future of animals in the food-producing chain. The dairy cow is a member of a group of animals called ruminants. Ruminants need not compete with man for sources of food. They rank high among the animal species that can convert materials unsuitable for human consumption into human foods. If it were not for the unique digestive process of the ruminants, millions of acres of grasslands and many byproduct feeds would go largely unused in the production of human food -- a waste that is hardly consistent with the critically increasing need for food. The transformation of the carbohydrates and proteins of forages into edible meat and milk would be extremely costly to duplicate by any chemical-synthesis method yet devised.

Among ruminants, the dairy cow is particularly efficient in transforming dietary nitrogen and energy into an edible product -- milk. A recent study shows that protein production by the milking cow is more efficient than either beef or swine and almost equal to poultry. When grains are available in excess of man's needs, but not in sufficient quantity to produce animal protein in accordance with man's present food-consumption pattern, it will be necessary to decide which kinds of animals will be fed. When the milking cow eats enough forage to satisfy her energy requirements for maintenance, she will provide a greater gain in protein production per unit of concentrates ingested than will any other farm animal.

It is clear that a healthy dairy industry is important both to the consuming public and to agriculture. With such an important industry, it is clearly in the public interest that a continuous aggressive program of dairy research be conducted to assure continued development of dairying.

The overall objective of the Dairy Production Research Program is to produce adequate amounts of safe and wholesome milk and milk products with optimum efficiency in the use of land, animals, and feedstuff resources, and with reasonable profit margins for producers, while maintaining a quality environment and conserving energy.

II. ARS NATIONAL RESEARCH PROGRAM SUMMARY

A. Current Technologies

Reproductive inefficiency is costly to dairy farmers. Five percent of all dairy cows fail to conceive. The true conception rate following artificial insemination is only about 50 percent and the calving interval is 13½ months as contrasted with the desired 12 months. Inefficient reproduction has two major causes. The first is delayed breeding which follows when cows do not exhibit estrus or when the herd owner fails to detect it. The second cause is failure to conceive following insemination. This occurs when (1) the ovum is not fertilized, or (2) when there is embryonic death.

Increased average herd size and the resulting reduced attention to individual animals, is one of the reasons for problems with reproductive efficiency. Another probable reason is the increased direct semen sales to producers. In some cases, dairymen do not handle semen properly and do not have the best artificial breeding techniques.

On the other hand, considerable progress has been made in understanding reproductive phenomena. Much more is known about the interplay of various hormones during the reproductive cycle. Encouraging developments have occurred with compounds such as prostaglandins with which estrus and ovulation can be manipulated. More is known about sperm transport in the female reproductive tract. Superovulation and embryo transplantation is more successful and more is known about culturing and preserving ova <u>in vitro</u>

Milk production per cow in the U. S. is extremely variable. In 1974, the average annual milk production per cow was 10,286 pounds. Far too many cows produce only 5,000 to 6,000 pounds per year. On the other end of the production spectrum, the best herds in the nation average more than 20,000 pounds per year. Recently, an Indiana cow produced more than 56,000 pounds of milk in a 365-day lactation.

If milk production declines during lactation could be slowed, milk production per cow could be increased substantially. More frequent daily milking would increase milk yields but economic considerations are significant. While 27 percent of the milking females are ultimately culled because of low production, poor producers can not be detected until they are at least 2½ years of age. Likewise, bulls used for artificial insemination must be kept until they are 5 to 6 years of age before their genetic transmitting ability for yield is really known. Methods of determining milk producing capacity of heifers at an early age would permit culling of both males and females at an earlier age than is now possible. Greater numbers of mammary secretory epithelial cells, more intense metabolic activity of mammary cells, and greater efficiency of the milk ejection reflex should result in greater milk production. An improved understanding of the basic mechanisms of milk secretion is needed if gains are to be made in milk production efficiency.

Since feed costs represent a large proportion of the total cost of milk production, dairymen are constantly striving to find ways of lowering them. Increased cereal grain feeding has been responsible for much of the increase in milk production achieved over the past 20 to 25 years. The increased world market for cereal grains however, has changed the feed situation so that it is likely that in the future, more forage will be fed than the 60 percent now used on the average in rations for dairy cattle. For the first time in many years, the amount of grain fed to dairy cows declined in 1974 compared to 1973.

Many advances have been made in our knowledge of dairy cattle nutrition, but in spite of these advances, numerous problems exist which limit utilization of nutrients by cows. When the proportion of forage in a ration increases, milk production usually declines. The digestibility of forage dry matter is about 50 percent compared to 75 percent for concentrate feeds. More information is needed on maintaining milk production at high levels when cows are fed high levels of forage in their diets.

Nutrient losses in harvested forages are excessive and average 25 percent of the dry matter. Under adverse weather conditions, losses are particularly high. Means must be devised to reduce or prevent these losses. More information is needed to identify more precisely the conditions under which heat damage of protein occurs in low moisture forage. Techniques which would enable one to predict nutritive value of forages for milk production more quickly and cheaply would be very useful. Feeding standards are widely used in dairy cow feeding, but there is reason to question the accuracy of the digestibility coefficients used in some current tables of feed composition. When cereal grains are plentiful and low priced, the varying digestibilities of cellulose under different conditions tend to be obscured. As more reliance is placed on cellulosic feeds, more knowledge will be needed to determine the factors affecting cellulose digestibility to determine whether cows with different genetic backgrounds differ in the efficiency with which they can utilize the products of cellulose digestion. Cellulosic wastes such as straw and corn fodder are so poorly digested that they are seldom used as roughages for lactating cows. Methods need to be developed to improve the utilization of these materials.

Nutrient requirement tables were developed, based on research with cows of only moderate milk producing ability. With an increasing number of high producing cows, nutrient requirement tables will need to be modified. A principal limiting factor to maximum milk production is the limited capacity of cows to consume dry matter. Methods of increasing dry matter intake should be developed. Improvement of efficiency in the utilization of digestible energy above maintenance requirement is needed. While non-protein nitrogen can be utilized, problems exist with its utilization when it is used as the only source of nitrogen for heavily lactating cows.

Technology in dairy cattle genetics has advanced considerably in the past decade. It is estimated that during the past ten years, genetic improvement has been at the rate of 60 lb. milk/cow/yr. Highly effective

techniques have been developed for estimating genetic transmitting ability of bulls for milk and fat yield from progeny information. Pedigree evaluation has progressed little. Milk components other than fat are not being evaluated. Economically important non-yield traits are not well understood and are having only minimal impact under present practices. The same is true of potentially high impact (both beneficial and detrimental) miscellaneous genetic effects. More efficient methods for collecting, transmitting and analyzing masses of data need to be developed and in making production testing information more appropriate to the dairyman's needs. The industry's use of superior germ plasm presently being identified by the USDA-DHIA Sire Summary and Cow Index Programs, is directly benefiting dairymen. This amount could be doubled within 10 years. The dairy industry could benefit by tens of millions of dollars per year through an accelerated rate of genetic improvement of dairy cattle for total economic merit.

In large dairy herds, cow handling, milking and feeding systems tend to discourage sufficient individual attention to feeding, breeding, milking and handling of cows. Even though a considerable body of knowledge exists on feeding cows, many good cows are underfed and poor cows are overfed. There is considerable opportunity for improvement of group feeding systems, record keeping systems and for streamlining decision making in culling and breeding. While substantial gains have been made in labor efficiency, many opportunities for improvements in efficiency exist in most dairy enterprises. Feeding, bedding and individual chores require 35 hours per cow per year and milking occupies an additional 25 hours. Many barns, lots, and feeding systems are not arranged so that labor can be kept to a minimum, although innovations in designs, housing and materials handling in large herds have resulted in substantial improvements. Since 40 percent of the total labor involved with a dairy herd is associated with milking, milking machine design such as the development of the automatic takeoff feature has appreciably improved labor efficiency, but considerable time is involved in pre-milking activities such as udder washing and stimulation of milk let down, in teat dipping and in sanitizing teat cups following milking. Likewise, while many choices are available to dairymen considering milking parlor construction, it is not completely clear which designs are best for herds of varying sizes. Neither have economic guidelines for optimum milking frequencies been established. Because of increasing environmental concerns, dairymen must devote much more effort and resources to manure collection and disposal than was true previously. Manure collection and disposal becomes a materials handling problem. The challenge of this problem is to handle animal waste as little as possible before disposing of, or utilizing it and with minimum opportunity for air, soil or water pollution.

Death losses to six months in calf rearing are about 15 percent. These losses are serious both because they represent a lost investment and because they substantially decrease the opportunity for selecting from among various animals for herd replacements. Climatic stresses reduce milk production, particularly in some locations. Certain areas could become much more suitable for dairying if inexpensive systems for counteracting climatic stress could be devised.

At the farm level, great gains have been made in technology enabling the dairy farmer to produce milk with a longer potential shelf life, a lower bacterial count, and minimum amounts of materials which might not be conducive to human health and well being. Rapid refrigeration, strict inspection procedures and hygienic milking practices with a minimum of exposure to bacteria and foreign materials, make whole milk and its products wholesome and nutritious. Per capita consumption of milk and certain dairy products has declined steadily. Consumption of nonfat constituents of milk has remained fairly steady. The drop in consumption arises almost exclusively from declines in whole milk and butter consumption. If current trends continue, emphasis should be placed on decreasing the fat content of milk and increasing levels of milk components such as protein. If milk fat content could be reduced by 25 percent and milk protein content increased by 25 percent, a product much closer to what the consumer seems to prefer would be available in the market place.

Mastitis, an infectious disease of the udder, is the most serious dairy cattle health problem. Reduced efficiency and increased cost result from reduced milk yield of infected cows, disposal of unsalable milk, early culling of valuable cows and treatment. Estimates of losses to the U.S. dairy industry attributed to mastitis vary from $400 million to $1 billion annually. These losses decrease income to dairymen and increase the cost of milk and dairy products to the consumer. Control and prevention of mastitis is complicated by the fact that many microorganisms are implicated and because a multitude of environmental and genetic factors influence frequency of infection. The involvement of specific herd management, sanitation practices, and milking machine characteristics and transmission and exacerbation of udder infections are not well understood. However, there are indications that many of these factors have a major impact on disease frequency. Effect of machine characteristics on mastitis incidence has lacked study due to the disinclination of the manufacturing industry to conduct disease-related research. The potential for increasing mastitis resistance through acquired immunity remains unknown. Therapy of mastitis is greatly hindered by lack of adequate and rapid diagnostic procedures.

B Visualized Technologies

Improved technology for use by the dairy producer will be achieved by the joint research efforts of the Agricultural Research Service and other research agencies of the USDA, the State Agricultural Experiment Stations and by the various facets of industry serving the dairy farmer. For its effective use, research findings must be transmitted to dairy producers by the research agencies, by county, state and federal extension services, and by industry, using appropriate media.

Within 10 years, calving interval should be shortened by 15 days and sterile cows reduced from 5 to 2 percent. Dairy farm losses of potential calves from cows which have conceived will be reduced from 10 to 4 percent and loss of poor reproducing bulls will be reduced from 7 to 3 percent. Some gain

will be made in controlling sex ratio of calves. A gain in annual milk production of 250 pounds per cow in a period of 10 years is anticipated as a result of increased understanding of milk synthesis. Physiological-biochemical studies will reduce the age at which animals can be culled for potential low production and the genetic worth of bulls can be established at a younger age.

By developing lower cost methods of improving the feeding values of forages, byproducts and nonprotein nitrogen for dairy cattle, and by developing feeding programs and standards to permit optimum commercial application of the developed technology, it is likely that the following improvements can be made. (1) Average digestibility of forages fed can be increased from 50 to 55 percent. (2) The use of oilseed meals now fed to dairy cattle can be decreased from 5.6 to 4.3 million tons. (3) The loss of nutrients in harvested forages can be decreased from 25 to 15 percent. (4) The proportion of feed nutrients obtained from forage can be increased from 60 to 67.5 percent. (5) The amount of cellulosic waste forages used in dairy feeds can be increased from nearly zero to 5 percent. (6) The proportion of lactation for which digestible energy intake is inadequate for the requirements of high producing cows can be reduced from 20 to 16 percent. (7) The utilization of digested energy for milk production above maintenance can be increased from 50 to 60 percent.

By putting into practice new technology developed in dairy genetics, dairymen would be able to select AI bulls from a group with transmitting abilities approximately 75 percent higher than at present. These bulls would also be evaluated for the economically important traits so that weaknesses in present cows could be corrected in future generations. The financial returns from an effective job of selecting bulls for use in a herd will be much greater than at present. Dairymen will be breeding more for total economic merit than only for high yield. If milk components other than fat become important in pricing schemes, genetic information will be available on their heritability. More sophisticated procedures for data acquisition, transmission and analysis will be used providing greater variety of information for genetic improvement at lower per unit cost.

Labor saving and more accurate dairy herd feeding systems will be used as a result of improved technology. Improved animal identification coordinated with computerized record keeping will result in better herd management. Improved housing and new equipment will reduce chore time by 8.7 hours per cow per year. Milking equipment will be improved and will result in more effective milking and a lowered incidence of mastitis. Labor required for milking will be reduced by 25 percent. Effective uses and handling of dairy cattle wastes will increase their value and will reduce environmental hazards. Effective calf feeding, housing and management systems will reduce calf losses from 15 to 8 percent. Simple, inexpensive but effective means of environmental control will reduce milk production losses due to unfavorable environment.

Even though per capita consumption of milk and dairy products decreases, total protein produced in the milk of dairy cows might increase if appropriate physiological research effort is conducted to increase the amount of protein in milk. Under these circumstances, the total amount of milk protein produced nationally could increase from a current level of 3.8 billion pounds to a level of 4.4 billion pounds. Also, with appropriate research and regulations, the amount of milk containing undesirable flavors and odors arriving at plants and the milk rejected for unknown causes could be reduced.

It is hoped and expected that improved technology will reduce the new infection rate from mastitis and will decrease the duration of infection. In addition, the proportion of the milk and meat supply rejected because of contamination with antibiotics will be reduced. These advances will be accomplished by breeding for resistance to mastitis and by improved detection methods. Improvement of milking machine characteristics will play an important role and more effective therapeutic measures should shorten the duration of infection and may reduce new infections. Knowledge of physiological defense mechanisms could lead both to means of preventing new infections and to improved therapy.

C Consequences of Combined Visualized Technologies

The combined technologies should lower the farm cost of milk production and therefore, reduce the cost of dairy products to the consumer. Technology will be developed which will have application to other farm animals. Increased utilization of forages and cellulosic wastes will decrease the competition between man and animals for feed grains and plant proteins. Threats to human welfare from diseased animals will be reduced. Many more specific benefits will accrue which relate specifically to numerous aspects of the dairy production practices and dairy herd management. These are itemized under each of the six Technological Objectives. On the negative side, as new technologies are developed, greater differences likely will exist between the most and least well managed dairy herd operations. This trend will continue to force operators of the less well managed dairy herds to discontinue dairying and will necessitate new employment opportunities for dairymen thus displaced.

D Total Potential Benefits

Item	Extent of Improvement	$ Value in 1985
		Million $
Reduce calving interval	15 days	135
Reduce sterile cows	5% to 2%	57
Reduce fetal and dead calf losses	10% to 4%	85
Reduce repeat breeding losses in AI	2.0 to 1.5 S/C	20
Offspring sex control	50-50 to 65-35	30

Reduce loss from infertile mature bulls	7% to 3%	1
Improve milk production efficiency	250 lb/cow/year	185
Reduce age for culling females	30 mo. to 18 mo.	91
Reduce time of bull proving	5 years to 4½ years	--
Total benefit from TO III.1, Improve Reproductive and Lactational Efficiency		604
Increase forage digestibility	50% to 55%	90
Replace part of oilseed meal	Replace 1/4	17
Reduce losses in harvested forage	from 25% to 15%	166
Substitute forage for grain	Decrease grain feed from 40% to 32.5%	123
Increase crop residue use	From nil to 5%	78
Feed best cows better	Reduce underfeeding from 20% to 16%	152
Define nutrient requirements more accurately	Increase precision from ±10% to ±5%	-
Increase milk production efficiency	Reduce feed required by 10%	123
Total benefit from TO III.2, Improve Feed Utilization Efficiency		749
Increased genetic improvement shown by improved Predicted Difference of bulls	from +64 lb. to + 113 (Increase of 49 lb)	150
Reduced cow replacement rate	30% to 24% (Improvement of 20%)	26
Lowered veterinary costs	$5 per cow	20
Reduce losses of high producing cows	+100 lb milk/cow	33
Improved statistical and computer technology	Difficult to assess	--
Recognition of genetic defects	Difficult to assess	--
Recognition of adverse or ignored genetic effects	Could have enormous impact	--
Total Benefit from TO III.3, Improve Genetic Capacity for Production		229
Better feeding systems		
Improved milk production	(See TO III.2)	
Decreased feed cost		
Better herd records		
Increased milk production	2.5%	236
Reduced labor	1 hr/cow/yr	23

Optimum herd grouping		
Increased milk production	1%	53
Reduced labor for dairy chores	8.75 hrs/cow/yr	196
Reduced labor for milking	6.25 hrs/cow/yr	140
Reduced death loss of replacement heifers	7% reduction	16
Reduced costs for treating sick calves	$4/calf	18
Replacement heifers enter herd earlier	1 month earlier	57
Improved environmental control		
Reduction in heat stress in South (Improved milk production)	2.5%	41
Reduction in cold stress in North (Improved milk production)	1%	21

Total Benefits from TO III.4, Improved Management Practices and Systems	801
Total Benefits from TO III.5, Improve Efficiency of Producing Quality Products	(None claimed in this NRP, See NRP 20600)
Total Benefits from TO III.6, Decrease Losses due to Diseases, Pests and Other Hazards	(None claimed in this NRP, See NRP 20420)
Total Potential Benefits Resulting from Dairy Production Research (ARS and SAES)	2,383

E Total Research Effort

(FY 1975)

Research Area	Current Effort ARS	Current Effort SAES	Expanded ARS Effort
Improved Reproduction and Lactation	5.7	42.1	11.2
Improved Feed Utilization	10.8	84.6	15.8
Improved Genetic Capacity	6.8	23.9	9.8
Improved Management	2.1	24.3	5.1
Improved Product Quality	(See NRP 20600)		
Improved Control of Disease Pests and Other Hazards	(See NRP 20420)		
Total	25.4	174.9	41.9

Note: The expanded support level reflected in this National Research Program represents staffs' views as to the additional level of staffing that can be effectively used in meeting the long-term visualized objectives for this program. These do not reflect commitments on the part of the Agency.

III.1 Improve Efficiency of Reproduction, Lactation and Other Physiological Processes

A. Current Technology

Milk production loss and losses of cattle caused by reproductive inefficiency is an important contributor to high production costs. The average dairy cow lives approximately 5 years, produces two offspring and completes two lactations. Reproductive failure is a major cause of short productive life. Even in well-managed herds, 5 percent of the cows fail to conceive each year and must be replaced. Artificially-bred cows require an average of about two inseminations per conception. The true conception rate for all services averages only about 50 to 55 percent. The average calving interval is more than 13 1/2 months for animals that calve at least twice. A 12-month calving interval is recommended because it results in the maximal and most profitable milk yield per cow per year. A 12-month interval also provides more calves from which to select herd replacements and permits calvings to be timed to take advantage of milk prices and feed and labor supplies.

The two broad categories of reproductive problems are (1) those that delay breeding, and (2) those that cause the loss of potential offspring following service, and thus necessitate rebreeding. Ovarian abnormalities, such as cystic follicles and long anestrous intervals, usually caused by one or more ovulations without detected estrus, delay breeding. Many estrous periods (about 1/2) are missed either because the animal did not exhibit estrus or because it was not detected by the dairyman. Loss of potential offspring following service is caused by ovulation failure, fertilization failure, and embryonic death. Fertilization failure occurs after about 15 percent and embryonic death after more than 20 percent of all services.

Reproduction problems are caused by physiological disorders, by disease or by faulty management. There is no known therapy for the physiologically based problems that will prevent or cure these reproductive disorders, except for cystic follicles. Considerable fundamental information on reproductive physiology has been acquired during the past 10 years. Research has contributed substantially toward understanding the complex relationships between the various glands and organs that regulate the reproductive processes. The brain, pituitary gland, ovaries, uterus and the developing embryo all contribute to reproduction. Research on the lifespan of the corpus luteum and pathways involved in the natural regression of corpora lutea have contributed to understanding the regulation of the estrous cycle.

Considerable research is now being devoted to the testing of natural and synthetic prostaglandins for use as corpus luteum regressing agents. These compounds are effective in inducing the regression of corpora lutea and thus in manipulating the time of the subsequent ovulation. Prostaglandin administration permits ovulation to be timed with sufficient precision that the need to detect estrus has been eliminated. Ovulation control will need to be refined and the safety of the chemicals used well established before estrus-controlling chemicals can be used in dairy cattle reproduction.

Natural mating has an advantage over artificial breeding in reproductive efficiency in dairy cows. The artificial insemination reproductive rate is not improving and, in fact, may be declining. One reason is that AI organizations are now selling more semen directly to dairymen. They have thus lost the ability to maintain reliable records on the fertility of bulls, with the result that bull fertility is almost certainly decreasing. Also, semen handling and insemination techniques on the farm are probably poorer than the techniques previously practiced by AI technicians. The increased herd size and less careful observation of individual cows has reduced the efficiency of estrus detection and resulted in cows being inseminated at less than optimum times in relation to ovulation. These factors all reduce fertility by lowering the rate of ovum fertilization.

Much additional research is needed to reduce embryonic mortality. Prospects are excellent for eliminating the reproductive inefficiency caused by long periods of anestrus, ovulation failure, and the failure of ovum fertilization. Basic information is now available for controlling and synchronizing ovulation in large numbers of cattle.

There is now no means of controlling the sex of calves born. Artificial insemination combined with ovulation control provides an excellent opportunity to implement procedures for predetermining sex. Research must be conducted on establishing differences between sperm cells bearing X and Y chromosomes to provide information that could be used to select between the two if sex of the calf is to be controlled.

Techniques have been perfected to transplant embryos between cows and this procedure is now being used with valuable dairy cows and with the "exotic" breeds of beef cattle. Development of nonsurgical ova transfer techniques will encourage use of embryo transplantation on a larger scale by the dairy industry. Combining ova culture and storage with nonsurgical ova transfer and sex predetermination of the embryo to be transferred, would intensify the use of embryo transplantation and accelerate the spread of superior germ plasm through dairy cattle.

The potential for milk production per cow in the United States is much higher than the current level of 10,286 lbs/year. Milk quantity produced by dairy cows reaches a maximum between three and six weeks post partum, then decreases progressively throughout lactation. If the lactation decline were more gradual, milk secretion could be increased substantially. Dairy cows are normally milked twice daily. Modern higher producing cows may respond profitably to increased milking frequency. Twentyfive to 35 percent of cows are culled annually from dairy herds. Low milk production accounts for 27 percent of the cows culled. Bulls must be kept for five to six years, while the results of daughters lactations are tabulated, before it is determined if they are suitable for use in artificial insemination. If accurate methods were available to determine the milk producing capacity of heifers at an early age, culling could be done much earlier at a great economic saving. Increased

milk production will result from greater number of mammary secretory epithelial cells, more intense metabolic activity of mammary cells, and greater efficiency of the milk ejection reflex. These processes are regulated by hormones which are measurable in blood serum and milk.

In order to detail the losses it is important to identify the basic causes of reproductive inefficiency and identify to what extent losses are sustained by the industry as a result of this inefficiency. Following are estimates of dairy farm losses related to reproductive failure:

Extended calving interval - The average U. S. dairy cow probably has a calving interval of about 13.5 months compared to a desirable interval of one year. Thus, 45 days are lost annually because of reproductive inefficiency. Estimates indicate that 20 of the above lost 45 days are caused by factors that delay breeding. This 20 days consists of (a) eight days lost because the cow is in the wrong stage of her estrous cycle to begin breeding at the desired time, (b) six days are lost because ovulation occurs without estrus and (c) six days are lost because the dairyman fails to detect estrus. The remaining 25 days of the total 45 days lost time is caused by reproductive failure following breeding. This 25 days is made up of (a) three days lost because of ovulation failure, (b) nine days lost because of ovum fertilization failure, and (c) 13 days lost due to embryonic death.

Sterile cows culled - The best estimates suggest that 5 percent of the dairy cows are culled from herds because of sterility. Of these 1 percent are culled because of persistent ovulation failure and 4 percent for failure to conceive after repeated services.

Loss of potential calves - On an annual basis, out of 100 cows which are fertile and are pregnant, about 10 do not produce live calves. Of this 10, 5 fail to carry their calf to term for one reason or another and 5 give birth to dead calves at or near term.

Lack of control over sex ratio of offspring - The dairy industry would gain immeasurably if it were possible to control the sex of the potential offspring at the time of mating. Many more females than males are needed to maintain herd size. If it were possible to control sex, the breeder could make only a few matings to obtain bull calves for use as potential sires for use by artificial insemination. The balance of the matings could produce heifer calves to use for replacement of the milking herd. This would offer opportunities for much more intense culling.

Poor reproductive performance in bulls - About 7 percent of all dairy bulls are lost because of poor reproductive performance. Particularly when a bull of great genetic potential must be culled because of poor reproductive performance, the loss to the dairy industry is substantial.

Low milk production per cow - While the average annual milk production per cow has more than doubled since 1950, the national average milk production is less than 1/2 of levels now attained by some of the best herds in the United States. The current national average is 10,286 lbs.

Age at culling for low production - Most dairy animals first calve at about 2 years of age. Before a useful record of their milk production is available they are at least 30 months old. Earlier information on a cows genetic ability would permit dairymen to cull poor animals at a much earlier age and reduce animal raising costs.

Time required to establish genetic worth of dairy bulls - Five or six years are required before the true genetic worth of a dairy bull can be established. Many daughters of a bull must be observed and they must be housed and fed in several environments. More rapid identification of superior sires would greatly accelerate genetic gain in dairy cattle.

B Visualized Technology

Because reproduction is so complex and because there are numerous gaps in our knowledge, only partial improvement in reproductive efficiency can be achieved within 10 years. Ovulation control can be applied on a much larger scale than is now true within 10 years providing it is established that there is no milk or tissue residue from using ovulation-controlling hormones. Many dairy herd owners will then be able to eliminate the time-consuming practice of estrus detection. Less time will be lost because of anestrus or because of estrus and ovulation occurring at an undesired time. Failure of ovulation can be greatly reduced with effective ovulation control. Within 10 years, new technology will improve sperm survival and transport in the female reproductive tract and will reduce fertilization failure. While problems from embryonic mortality will be difficult to solve, basic research findings should result in some reduction in embryonic deaths. Increased research on the fundamental causes of sterility should reduce its incidence and knowledge of factors causing fetal death should lead to a reduction in calf losses. Sex control of offspring may be achieved within 10 years, but it will first be necessary to develop techniques for separating X and Y-bearing sperm cells.

The basic mechanics of milk synthesis are not well understood. Scientists do not know precisely why one cow can produce milk more efficiently than another even though each may be eating the same level of nutrients. Until we understand all of the highly complex problems relating to milk synthesis, progress in improving dairy cattle will be confined to milk production information gathered after the cow has initiated lactation. Hormonal, enzymic and other biochemical studies, both qualitative and quantitative, should provide improved understanding of milk synthesis. Such knowledge may enable dairy producers to identify females with the potential for both high and efficient levels of milk synthesis long before they initiate lactation. More understanding of the physiology of milk synthesis may also lead to methods which can be used to stimulate milk yield during early lactation and reduce the decline in milk yield as lactation advances. Additional understanding of the physiology of milk synthesis may also provide methods of artificially inducing lactation in barren cows to the point where the procedure would be both predictable and economically feasible.

The degree to which improvement can be made in problems related to reproductive efficiency depends on (1) the effectiveness of the research effort of the Federal, State and industry scientists; (2) the acceptance and use of the research findings by dairy producers; (3) the absence of unknown negative factors which might contravene the positive effects of the research findings. It is difficult to predict the extent of improvement in reproductive efficiency in dairy cattle by 1985, but the following goals seem attainable:

<u>Reduction in calving interval</u> - The calving interval should be reduced from 13.5 to 13.0 months. This would include reducing factors which delay breeding from 20 to 11 days of lost time. Use of ovulation-controlling compounds would eliminate entirely the need for cows to show estrus and the need for estrus detection. Time lost from reproductive failures following breeding could be reduced from 25 to 19 days. This would include reducing days lost from ovulation failures from 3 days to 2. Time lost due to ovum fertilization failures would be reduced from 9 days to 4. Improvement in time lost due to embryonic deaths will be more gradual, but a reduction from 13 days to 11 days seems reasonable.

<u>Fewer sterile cows</u> - Technological gains in understanding and treating sterility should reduce losses from the current level of 5 percent to about 2 percent. This would include reduction in losses from persistent ovulation failure from 1 percent to 0.5 percent and from failure to conceive after repeated services from 4 percent to 1.5 percent.

<u>Lower potential calf loss</u> - The application of new research findings should reduce dairy farm losses of potential calves from cows which have already conceived from 10 percent to 4 percent. It is expected that fetal deaths can be reduced from 5 percent to 2 percent and loss of calves born dead by the same amount.

<u>Offspring sex ratio control</u> - Since the level of control of sex ratio in offspring is now zero any move would be a gain. An improvement from the current 50-50 ratio to 65-35 appears possible in 10 years.

<u>Reduction in poor-reproducing bulls</u> - Better understanding of causes of poor male reproductive performance should reduce losses from the current 7 percent to a level of about 3 percent.

<u>Gains in milk production related to improved understanding of milk synthesis</u> - An improved understanding of the physiology of milk secretion is expected to increase milk production by 250 lbs per cow in 10 years from the current level of 10,286 lbs.

<u>Reduced age of culling for low production</u> - If techniques are developed by which milk production level can be predicted at an early age, the age for culling, an unprofitable animal could be reduced at a great saving in feeding and maintenance costs.

Reduced time needed for establishing genetic worth of bulls - If the potential worth of a female as a milk producer could be determined at an early age, the genetic worth of bulls could be established much sooner than the current 5 to 6 years of age. This would provide a great saving in the feeding of and caring for unprofitable animals.

C Research Approaches

The research approaches will be multi-disciplinary with a large share of the effort being basic in order to uncover fundamental mechanisms that will either correct or lead to the correction of failures in the reproductive process. (See also NRP's 20420, 20360 and 20380)

1 Shorten the interval between calvings.

a Develop methods that would permit pregnancy to be initiated at a specified time after parturition. (NER, Beltsville, MD)

(1) increase the rate of post-calving uterine involution and other phenomena that are necessary for the establishment and maintenance of a new pregnancy.

(2) develop methods to induce regression of corpora lutea at any stage of the estrous cycle.

(3) develop methods to regulate the time and number of ovulations.

(4) improve the transport and retention of sperm cells within the female reproductive tract.

(5) improve fertilization rates.

b Improve post-conception embryo survival rates. (NER, Beltsville, MD)

(1) elucidate the causes of early embryonic death.

(2) define the nutritional relationships between the embryo and dam.

(3) define the endocrine and immunologic interrelationships among the semen, dam and embryo during pregnancy.

(4) define the physiological mechanisms responsible for lowered fertility during certain situations of environmental stress and high lactational stress.

2 Minimize the losses resulting from maintaining cows of low fertility.

a Improve methods of heat detection. (NER, Beltsville, MD)

b Improve method for detection and treatment of ovarian cysts. (None)

c Improve methods of early pregnancy diagnosis. (None)

d Develop and improve methods to manipulate ova and embryos, including collection and transplantation, in vitro fertilization and culture, and long term storage. (None)

3 Control the sex of offspring.

a Elucidate the differences between X and Y bearing sperm cells. (None)

b Develop methods to separate X and Y bearing sperm cells. (None)

c Develop methods for sexing newly fertilized ova. (None)

4 Reduce the infertility of bulls.

a Define the causes of poor semen quality and improve techniques for evaluation of semen quality. (None)

b Improve the post-storage fertilizability of sperm cells. (None)

c Increase the gamete production of bulls with superior genetic merit. (None)

d Reduce problems with fertility related to advancing age. (None)

e Increase knowledge of control of spermatogenesis and male endocrinology. (None)

f Reduce age at puberty. (None)

5 Increase the average annual milk production per cow

a Demonstrate how physiological limitations in the control of milk yield can be overcome. (None)

b Identify the hormones which are rate limiting to mammary development and milk synthesis. (None)

c Relate differences in milk yields to clearance rates of hormones from the blood. (None)

d Determine mammary gland uptake of hormones and quantities of hormones bound to secretory mammary epithelial cells in low and high producing cows. (None)

e Determine if optimum hormone levels can be attained by breeding, control of the environment, or administration of other synthesized or naturally occurring compounds. (None)

f Determine if direct administration of rate limiting hormones will increase milk production. (None)

g Develop methods and evaluate the practice of blocking hormones that inhibit lactation. (None)

h Develop methods to artificially induce and maintain lactation. (None)

i Reduce the loss of milk due to decline in production as lactation progresses by determining the physiological mechanisms which cause the decline and developing counter measures. (None)

6 Develop methods for predicting potential milk producing ability of females at an early age.

a Determine if differences in the hormone profiles of young calves are related to subsequent milk production. (None)

b Evaluate thermography and mammography as methods of quantitatively measuring the amounts of mammary development in calves. (None)

c Develop new methods to measure quantitatively the amount of mammary development in calves. (None)

D Consequences of Visualized Technology

1 Lower farm cost of milk production

2 Lower the cost of dairy products to consumers

3 Contribut technology that will lead to greater reproductive efficiency in other farm animals.

4 Contribute technology to the reproductive and over-population problems of mankind.

5 Reduce length of time required to determine genetic ability.

6 Contribute to knowledge of milk synthesis in all species.

7 Contribute to dietary needs of man.

8 Provide dairy products for export.

E Potential Benefits

The following statistics were used and assumptions were made in calculating the potential benefits from improved reproductive efficiency:

Milk cows	11.2 million
Milk production per cow	10,286 lbs.
Total milk production	115 billion lbs.
Value of dairy farm production	milk $9.7 billion dairy beef $2.2 billion
Milk needs by 1985	118 billion lbs.

The current situation and the affected gains in reproductive efficiency are a result of new technology arising out of research are explained in III.1 A and B. Details of the stepwise calculation of potential benefits are shown in the Appendix, pages 75 to 78.

The table below shows in condensed form the expected $ gains from improved reproductive efficiency in dairy cattle by 1985:

Potential Benefits in 1985 from Research to Improve Reproductive Efficiency

Item	Extent of Improvement	Value in 1985 Million $
Reduce calving interval	15 days	135
Reduce sterile cows	5% to 2%	57
Reduce fetal and dead calf losses	10% to 4%	85
Reduce repeat breeding losses in AI	2.0 to 1.5 S/C	20
Offspring sex control	50-50 to 65-35	30
Reduce loss from infertile mature bulls	7% to 3%	1
Improve milk production efficiency	250 lb/cow/year	185
Reduce age for culling females	30 mo. to 18 mo.	91
Reduce time of bull proving	5 years to 4½ years	--
TOTAL		604

F Research Effort[1]

	Current Support			Expanded Support
	Year	SY[2]	Gross $[2] X 000	SY's (ARS only)
ARS	1975	5.7	525	8.2 (Reprod. Phys.) 3.0 (Lact. Phys.)
SAES	1975	42.1	4,099	
Others	Not available			
Total		47.8	4,624	11.2

Years required for ARS and related SAES research to achieve Visualized Technology 10

[1] From Inventory of Agricultural Research, FY 1975, Vol I, CSRS, USDA, March 1976

[2] Represents total SY's and $ in RPA 310 (Reproductive Performance)

III.2 Improve Efficiency of Feed Utilization

A Current Technology

(This Technological Objective is related to NRP 20100, Forage Crops Production; 20400, Livestock Structures and Equipment; 20520 Processed Field Crops; 20360, Beef Production, and 20380, Sheep and Other Animal Production).

Dairy products have been an economic source of nutrients partly because tremendous increases in milk production per cow have offset the rapidly increasing labor and overhead costs of producing milk. Much of this increase in production was achieved by greatly increased feeding of cereal grains and other concentrated feedstuffs. This was possible because of their relatively low cost. The increased world market for these grains has totally changed the dairy feed situation however, so that it is now imperative that reliance on large amounts of cereal grains for dairy cattle be reduced in favor of a systematic program of increasing the use of forages and other feedstuffs of relatively lesser value to humans.

Improved feed efficiency can be realized from improving the productive value of presently used feeds, substituting a lower cost feed for a presently used feed, developing additional feed sources from presently useless material, determining more precisely the productive value of various feeds, and by eliminating the waste of over and/or under feeding.

Research has indicated that improved feed efficiency may be possible through the application of new technology. It has been demonstrated, for example, that protein feeds can be completely eliminated from the diet of dairy cattle. In this case proteins and amino acids are synthesized from nonprotein materials such as urea to provide the dietary requirement. Milk yield is substantially lower, however, on protein free diets than on normal diets and the effectiveness of nonprotein nitrogen sources is greatly diminished at higher levels of feed intake and milk production.

Chemical analyses of feeds has shown that the relative indigestibility of plant fiber is associated with the presence of specific interfering substances such as lignin or organic silica. Identifying the interfering substances has provided the basis for an improved digestibility prediction based on chemical analyses. Initial steps toward improving feed digestibility by chemical treatment have been based on this knowledge of interfering substances.

High fossil fuel costs have limited the use of artificial drying of forages and corn grain and has led to preservation of these materials with organic acids. The effectiveness of these acids in preserving the nutrient value of these feeds is not well established.

The value of ensiling as a forage preservation method has been extended and increased by the development of low moisture silage systems. This approach has improved preservation rates and animal performance for many farmers,

although heat damage to these stored forages causes the loss of 25 percent of forage protein by reducing digestibility. Formic acid is now being developed as a preservative for high moisture silage. Its use eliminates much of the loss and nutrient degradation normally occurring during natural fermentation.

The development of methods for using low cost systems for handling and storing forage has yielded economic benefits to the users. The cost per ton of storage capacity among differing types of silos varies by a factor of ten. Proper use and management of the lower cost storage units can contribute considerably to lower production costs.

The conversion of feed energy to milk energy involves major but not constant energy losses. It has been found that about 60 percent of the digested energy above maintenance requirements is converted to milk when some rations are fed, whereas, about 50 percent conversion is commonly observed.

The extent to which animals differ in their response to identical rations is indicative of genetic X feed interactions. Although the basic reasons for this interaction remain obscure, the superiority of some families on high forage rations has been observed. (See also TO III.3, page 35). Emphasis on maximum production per cow has tended to mask cows and/or diets which result in efficient conversion of cellulosic materials to milk.

At present, many commercial dairy farms are losing 25 percent or more of their forage crops by weather damage, shattering, losses in storage, and feeding wastes. The forage available is frequently 50 percent or more indigestible, and differences in the net energy value of feeds are frequently not recognized. Crop residues such as straw and corn stalks are not used to any extent because of their low feeding value. Many other byproducts of milling and other human food processing industries are available and are being used to an increasing extent although procedures for determining nutritive value are not readily available. It is unlikely that proposed research would eliminate concentrates from the rations of high yielding cows. However, as cereal grains become increasingly costly, their replacement with lower cost feeds of comparable energy values seems indicated.

Specifications

1	Average digestibility of forages fed	50%
2	Oilseed meals now fed to dairy cattle	4.6 mil. tons
3	Loss of harvested forages	25%
4	Proportion of feed nutrients obtained from forage	60%
5	Cellulosic waste forage used in dairy feeds	1%
6	Proportion of lactation for which digestible energy intake is inadequate for the requirements of high producing cows	20%
7	Precision with which nutrient requirements for growth and maintenance, pregnancy, and production of meat and milk can be defined	±10%
8	Utilization of digested energy for milk production above maintenance	50%

B Visualized Technology

The purpose of the research to be undertaken under Technological Objective III.2 is to develop lower cost methods of improving the feeding value and intake of forages, byproducts and nonprotein nitrogen for dairy cattle, and develop feeding programs and standards to permit optimum commercial application of the development technology.

It should be possible, using appropriate Research Approaches, sufficient research support and an effective system of transmitting research results to dairy producers to attain the goals listed below:

Increase forage digestibility - It is expected that within 10 years the average forage fed U. S. dairy cows will average 55 percent digestible dry matter. This would be a gain of 10 percent in digestibility (10 percentage units). The improvement would be achieved by studying the plant components interfering with digestibility, developing and feeding higher-quality forage species, by improved forage harvesting techniques, and by improving ration nutrient balance to promote more efficient digestion. Much of this research should be undertaken cooperatively with that described in NRP 20100.

Less oilseed meals fed to dairy cattle - Soybean meal, cottonseed meal and other byproducts of the oilseed industry are widely used as sources of supplemental protein for dairy cattle. Normally, they are the most expensive ingredients of the dairy ration. If prices are favorable, various sources of nonprotein nitrogen such as urea can be used to replace some of the nitrogen furnished by oilseed meals. Improved technology should permit more effective use of nonprotein nitrogen sources, freeing oilseed meals for use by nonruminants. Oilseed meal usage can also be reduced by more reliance on high protein forages and by developing higher protein content cereal grains. Increased ude of new sources of protein (single cell protein, animal excreta) will also decrease oilseed meal usage. This combination of approaches should permit a decrease of 25 percent in the usage of oilseed meals by dairy cattle.

Decrease loss of harvested forages - The tremendous loss of dry matter in the process of forage harvesting justifies substantial research attention. A team effort involving animal scientists, agronomists and agricultural engineers is imperative. (See NRP's 20100, 20400 and 20520). The role of the dairy scientist is to examine the nutritive value of forage prepared by improved harvesting techniques. A strong team effort to decrease forage harvesting losses should reduce average dry matter losses from the current 25 percent to a more acceptable 15 percent by 1985.

Increase nutrients obtained from forage - Dairy cows, like other ruminants, can live and thrive on diets where cellulose is the principle carbohydrate. Considerable effort must be directed toward more efficient utilization of forage energy. This will enable dairymen to feed their cows a higher proportion of forage with a resulting lower feed cost and will free feed grains for use by nonruminants. An increase from the current 60 percent to 67.5 percent of the total ration nutrients as forage should be possible by 1985. (This research is closely related with that undertaken in NRP 20100)

Increase use of cellulosic wastes - A tremendous ruminant feed resource exists in the form of cellulosic wastes. Cereal grain straws, corn and sorghum stovers, straw residues from grass seed production, food processing residues and wood wastes are all materials which have potential as ruminant feeds. To make the best use of these products, technology must be developed which will free cellulose from substances such as lignin and silica which interfere with its digestibility. Use of alkalies, such as sodium or ammonium hydroxide, or fungal lignases offer some hope for improved cellulose utilization from waste products. Within 10 years, advancing technology should provide an increase from essentially no utilization of cellulosic wastes by dairy cows to a situation where 5 percent of the total forage nutrients are derived from cellulosic wastes.

Improve feeding of high-producing cows - Extremely high-producing cows simply cannot consume enough nutrients to meet their daily needs for milk production. Nutrient consumption is limited not only by the physical capacity of the cow but by the rate of digestion and the rate of passage of the ingesta. Cows which achieve unusually high levels of production invariably have a tremendous capacity for feed consumption. Additional emphasis on research to increase food intake aimed at more adequately meeting the nutrient needs of high-producing cows, should reduce the proportion of lactation during which high-producing cows are inadequately fed from 20 percent to 16 percent.

Define nutrient requirements more accurately - Even though research on the nutrient requirements of dairy cows has been underway for many years, it is estimated the precision is no better than 10 percent of actual needs. In 1976, dairymen are dealing with a cow capable of producing much more milk than was true of the dairy cows of the 1940's and 1950's. Research will not only provide better answers to the question of nutrient needs of high producers but will also provide insights into nutrient interrelationship. The latter may have a profound effect on nutrient utilization. New technology will also provide answers on limiting nutrients in milk production, effect of feeding systems and effects of early nutrition on subsequent performance. Precision of feeding can be improved from ± 10 percent to ± 5 percent with sufficient research effort on these problems.

Increased milk production efficiency - Although milk production per cow has increased substantially, many scientists question whether substantial gains have been made in milk production efficiency. When nutrient requirements for maintenance are subtracted from nutrients consumed, it appears that nutrient utilization from milk production is little better, if any, in 1975 than it was in 1950. Research on interaction of physiological and nutritional factors and on how chemical and physical properties of feed affect the efficiency of nutrient utilization should improve the utilization of digestible energy above maintenance from the current 50 percent to about 60 percent.

C Research Approaches

1 Increase the digestibility of conventional forages.

a Determine chemical characteristics which are important in determining the digestibility and net energy (NE) of forages. (NER, Beltsville, MD)

b Study aspects of forage production which affect digestibility and NE of the crop. (NER, Beltsville, MD; SR, Lewisburg, TN; WR, Logan, UT)

c Ascertain how physical form affects the digestibility and NE of forages. (WR, Logan, UT)

d Study relationship of forage digestibility and NE value related to level of concentrate feeding. (NER, Beltsville, MD)

e Characterize maturity, digestibility, and NE relationships of alternative forage crops.(SR, Lewisburg, TN)

f Determine importance and genetic control of individual animal differences in digestive and productive efficiency. (NER, Beltsville, MD)

2 Reduce the amount of natural protein required in dairy cattle rations.

a Study efficiency of use of natural feed protein sources. Determine how they can be treated, supplemented or rationed to control solubility. (NER, Beltsville, MD; SR, Lewisburg, TN)

b Study the effect of nitrogen source on fiber digestion, NE value of the ration, nitrogen balance, voluntary feed intake and rumen microflora. (NER, Beltsville, MD; SR, Lewisburg, TN)

c Determine how level and source of nitrogen affect vitamin, mineral and energy requirements. (None)

d Ascertain effect of feed preparation and feeding on utilization of NPN. (NER, Beltsville, MD)

3 Reduce loss of forage crops occurring between the standing crop and animal consumption.

a Study plant and environmental factors which affect the range and extent of respiration losses in cut plants drying in the field. (None)

b Compare effectiveness of chemical or physical treatments in reducing field respiration losses. (NER, Beltsville, MD)

c Compare effectiveness of chemical or physical treatments on reducing the dry matter, energy and protein losses in stored forages. (NER, Beltsville, MD; SR, Lewisburg, TN)

d Determine how protein solubility can be decreased during wet storage. (NER, Beltsville, MD)

e Study storage structures or facilities which will decrease nutrient losses from stored forage. (NER, Beltsville, MD; SR, Lewisburg, TN)

f Develop crop preservation systems best adapted to small unmechanized farms and to large commercial farms. (NER, Beltsville, MD; SR, Lewisburg, TN; WR, Logan, UT)

4 Increase average level of nutrients from forage to a higher percentage of the total ration. This is dependent to a large extent on attaining the basic objectives of increased digestibility in forages under 1 above.

a Study effect of particle size, rate of fermentation, extent of digestion and end products of digestion on forage intake. (NER, Beltsville, MD)

b Compare effects of various concentrate feeding levels on intake levels of several forages. (SR, Lewisburg, TN)

c Study effect of differential cycles of feeding above and below energy requirements on milk production. (None)

d Determine which forages and preparation methods produce a product most palatable to dairy cattle. (NER, Beltsville, MD)

e Study chemical and structural factors which control the rates at which forages are digested. (NER, Beltsville, MD)

f Study methods for eliminating metabolic stress such as that sometimes observed on all corn silage diets. (NER, Beltsville, MD; SR, Lewisburg, TN)

g Develop an inexpensive and rapid measure of forage nutritive value. (NER, Beltsville, MD)

h Develop a method for measuring pasture productivity. (None)

5 Improve the digestibility and/or intake of cellulosic waste forages so that they become useful feed sources:

a Study chemical and physical factors limiting the rate and extent of fermentation of high lignin feedstuffs. (NER, Beltsville, MD)

b Examine chemical and physical treatments which can economically improve the digestibility and NE of high lignin forages. (NER, Beltsville, MD)

c Identify digestion inhibitors which occur in forage plants and establish how they influence digestibility. (None)

d Determine what type of nitrogen supplementation of cellulosic waste forage which is most economical and beneficial. (NER, Beltsville, MD)

6 Increase the level of digestible energy intake for high-producing cows during early lactation.

a Identify physical or chemical feed characteristics which tend to limit energy intake. (NER, Beltsville, MD; WR, Logan, UT)

b Identify physiological and metabolic parameters which limit feed intake. (None)

c Determine the effect of feed processing methods on digestible energy intake. (WR, Logan, UT)

d Study how feed characteristics affect rates of feed passage through the digestive tract. (NER, Beltsville, MD)

e Study prepartal exercise as a means of increasing feed intake. (WR, Logan, UT)

7 Increase the precision with which nutrient requirements are defined and with which rations can be formulated.

a Establish metabolic requirements of energy, minerals, vitamins, amino acids, and protein for each of the physiological functions. (NER, Beltsville, MD)

b Study the relationships among specific ration components and the dietary requirements for each nutrient for each physiological function. (NER, Beltsville, MD; SR, Lewisburg, TN)

c Determine how nutritional deficiencies contribute to stress and metabolic disorders. (NER, Beltsville, MD)

d Establish the effect of group feeding on ration formulation for meeting individual requirements. (See also TO III.4, p 45) (NER, Beltsville, MD; WR, Logan, UT)

e Determine the effect of premixing of all ration components and group feeding on the value of the ration for individual animals. (None)

f Determine how the nutrient availability of a specific feedstuff can be determined simply and economically. (NER, Beltsville, MD)

g Show which specific nutrients most commonly limit milk yield. (NER, Beltsville, MD)

h Study interrelationships which exist between calf management systems, stress and nutrient requirements. (NER, Beltsville, MD) (See also TO III.4, Page 47)

8 Reduce the loss of digested protein and energy during the conversion to milk energy.

a Study chemical and physical properties of feeds which interact to affect the efficiency of nutrient utilization for milk production. (NER, Beltsville, MD)

b Determine physiological and nutritional factors which interact to affect the efficiency of nutrient utilization for milk production. (NER, Beltsville, MD)

c Determine the factors which influence the amount of energy lost as methane. (NER, Beltsville, MD)

d Find how preparation methods affect the efficiency of utilizing grain. (NER, Beltsville, MD)

D Consequences of Visualized Technology

1 Reduce the farm cost of producing milk and meat from dairy cattle.

2 Reduce the cost of dairy products to the consumer.

3 Contribute to increased feed efficiency in other farm animals.

4 Reduce the competition between dairy animals and man for feed grains and proteins.

5 Utilization of additional crop residues for dairy cattle feed.

6 Improve the economic advantage of dispersing dairy cattle over forage and crop residue areas; thus, reducing the pollution problems caused by high concentrations of dairy cattle.

7 Reduce the need for protective pricing of dairy products.

8 Release some land for recreational and other nonfarm uses.

9 Contribute toward rural development.

10 Contribute to the maintenance of a desirable rural-urban balance.

E Potential Benefits

In calculating the total potential benefits from the Visualized Technology, certain assumptions have been made concerning current situation as follows:

Division of Nutrient source	60% forage, 40% concentrate
Cost per ton of forage (TDN basis)	$120.00
Cost per pound of forage (TDN basis)	$ 0.06
Cost per ton of concentrates (TDN basis)	$180.00
Cost per pound of concentrates (TDN basis)	$ 0.09
Feed cost per 100 pounds of milk	$ 3.55
Feed cost per 100 pounds of milk (above maintenance)	$ 2.38

Details of the calculations used in ariving at the values shown in the table below are shown in the Appendix, pages 78 to 81

Item	Extent of Improvement	Value in 1985 Million $
Increase forage digestibility	50% to 55%	90
Replace part of oilseed meal	Replace 1/4	17

Reduce losses in harvested forage	from 25% to 15%	166
Substitute forage for grain	Decrease grain fed from 40% to 32.5%	123
Increase crop residue use	From nil to 5%	78
Feed best cows better	Reduce underfeeding from 20 to 16%	152
Define nutrient requirements more accurately	Increase precision from ±10% to ±5%	--
Increase milk production efficiency	Reduce feed required by 10%	123
TOTAL		749

F Research Effort[1]

	Year	Current[2] SY's	Support[2] Gross Dollars X 000	Expanded Support SY's (ARS Only)
ARS	1975	10.8	625	15.8
SAES	1975	84.6	10,179	
Others		Not Available		
TOTAL		95.4	10,804	15.8

Years required for ARS and related SAES to achieve Visualized Technology 10

[1]From Inventory of Agricultural Research, FY 1975, Vol I, CSRS, USDA, March 1976

[2]Represents total SY's and $ in RPA 311 (Biological Efficiency) less SY's and $ in RPA 311, Field of Science 0510 (Genetics and Breeding)

III.3 Improve Genetic Capacity for Production

A Current Technology

Production of the average cow in the United States increased from 4,622 to 10,286 lbs. annually between 1940 and 1974. Part of this increase in production can be attributed to improved feeding and management. Substantially more grain was fed on the average to cows in 1974 than in 1940, and this was responsible for a portion of the increased milk production. In addition, management procedures and disease control have improved during this period. Improved genetic ability has been responsible for a significant proportion of the improved production. Genetic gains have been particularly noticeable for the past 10 to 15 years. These gains are coincident with more advanced methods of identifying genetically superior dairy cows and bulls.

Dairy cattle genetics research has been conducted for many years using institutionally-owned dairy herds. There are more than 9,000 dairy cows in 73 dairy herds owned by the State Agricultural Experiment Stations and USDA. Many of these herds have been used for genetic studies. In addition, records generated in the National Cooperative Dairy Herd Improvement Program (NCDHIP) are an important and highly-valuable source of dairy cow performance information which can be used in dairy cattle genetics research. Milk production and composition records on 2 1/2 million cows annually are available through the NCDHIP and these records provide a unique resource for measuring the genetic abilities of dairy bulls actually being used in the nation's dairy breeding program. This type of information is unparalleled in any other species of domestic farm animals. Even though progress in genetic research has been steady and the genetic potential for milk production has been increasing, there is considerable genetic potential for increasing milk production.

Selection for yield of milk and milk components - Marked progress has been made in the past 10 years in the accuracy and effectiveness of selection for the yield of milk and milk components. During this period the average annual milk yield of cows in the NCDHIP on official test has increased by 1,478 pounds from 11,685 lbs. to 13,163 lbs. Of this, probably 600 lbs. is due to genetic improvement. During the same period, the average Predicted Difference (PD) of bulls active in artificial insemination (AI) has increased from +100 to +425 lbs. A much larger segment of the dairy industry is using available genetic technology (USDA-DHIA Sire Summaries) than was true in 1966. The technology for evaluation of bulls using progeny information has advanced markedly in the past 10 years but technology of pedigree evaluation has progressed very little. Although the initial use of PD as a dairy cattle genetic tool represented an appreciable advancement over previously used sire proving techniques, the Modified Contemporary Comparison (MCC) procedure first used in 1974 represents a substantial advance over the Herd Mate Comparison procedure. The MCC uses both progeny and pedigree information. The linear model methodology now under development provides hope for still further refinement of the sire proving techniques. Although some bulls are selected for AI progeny testing on the basis of natural service progeny tests, most are selected

on the basis of pedigree information. "Designed" progeny tests are only now starting to be used. Further cooperative efforts involving ARS, SAES and the dairy industry should further strengthen this program.

Identifying and genetically evaluating economically important non-yield traits - Because of the advances made as a result of research related to the NCDHIP, selection for milk production has progressed significantly. However, many traits which have no immediate bearing on milk yield, also are very important. Those traits which must be identified, quantitated and genetically evaluated include reproductive performance, susceptibility to mastitis, milking speed, growth, and certain facets of anatomical structure related to longevity. Many of the most important traits are not being evaluated at present. Technology is rather poorly developed in this area but needs for improved technology are increasing rapidly due to higher yield and accompanying stress. Little is known about the inheritance of non-yield traits or the possible interrelation between these traits and the inherited ability for milk production. Some progress has been made in identifying non-yield traits particularly those related to physical conformation by the various purebred dairy breed organizations. The type classification program has sought to describe the anatomy of animals in a systematic fashion. One breed association used PD for type based on daughter-dam comparisons. Various AI organizations have initiated physical confirmation appraisal programs and have been involved in breeding dairy bulls. Several use gross screening techniques on easy-to-measure traits. The dairy industry's effort, while useful as far as it goes, is poorly organized and not well standardized. In addition, from an economic standpoint, there has been too much emphasis on physical confirmation (i.e. type) thereby lowering selection differential for yield. Currently, a spontaneous industry effort is developing to study one important non-yield trait (i.e. calving difficulty).

Statistical and Computer Technology - Tremendous advances have been made in statistical and computer technology as related to dairy genetics research. The current favorable position of dairy cattle genetics information is directly related to effective use of computers in genetics research. The use of computers for this purpose has been at least as far reaching in its effect on the dairy industry as developments such as refrigerated tanks, freestall housing and the development of elevated milking parlors. The USDA-DHIA Modified Contemporary Comparison (MCC) is much more accurate than the Herdmate Comparison but is expensive to run due to massive data files and iteration procedures. The consequences of limiting the data pool to a limited time span or number of lactations per cow is not well understood. Little research and development work has been conducted on computer system efficiency. Linear model methodology has potential for lowering computer costs, but problems which exist with some frequency with dairy records create some difficulties when using linear model methodology and cow index methodology is not developed for this procedure. Procedures for data acquisition and automation are severely limiting in large herd situations.

Adverse or ignored genetic effects as related to present technology - Current recommendations on dairy cattle breeding place strong emphasis on milk production. Bulls are most frequently chosen on the basis of their PD for milk since the current economic situation appears to dictate the use of PD-milk as the most important selection criterion. This breeding technique means that relatively few bulls are widely used and the genetic base is thus narrowed. Little is known about the long-term effects of narrowing the genetic base. In addition, little attention is paid to potentially advantageous or deleterious genetic effects that may be operating in the population due to widespread use of present technology. Notable examples exist in other species such as the porcine stress syndrome in swine, the reproduction problem with turkeys and the problem with the dwarf recessives in beef cattle in the 1950's. Questions are frequently asked concerning whether selection based on performance when cows are fed high levels of concentrates is valid when the diet is based largely on forages. Furthermore, genetic improvement today is based almost entirely on mass selection. Non-additive genetic effects such as nicking, gene-environment interactions and maternal effects are being virtually ignored. Furthermore, the industry is faced with the possibility that research conducted 5 to 25 years ago may be invalid because of the rapid increase of the production level of the population. Finally, while other countries have emphasized a combination of dairy-beef animal, beef producing qualities of dairy bulls have been virtually ignored in our current dairy cattle selection procedures.

B Visualized Technology

The industry's use of superior germ plasm presently being identified by the USDA-DHIA Sire Summary and Cow Index Programs is of direct benefit to many dairymen. This benefit could be markedly increased by a combination of more efficient use of existing research resources and the investment of some additional resources.

Assuming that well planned and executed research is conducted, the results would be that dairymen would be able to select AI bulls from a group with transmitting abilities appreciably higher than at present. These bulls would also be evaluated for economically important traits so that weaknesses in the present cows could be corrected in future generations. The financial returns from an effective job of selecting bulls for use in a herd would be much greater than at present. Dairymen would be breeding more for total economic merit than just for high yield. If milk components other than fat become important in pricing schemes, genetic information would be available on them. More sophisticated procedures for data acquisition, transmission and analysis would be used providing greater variety of information for genetic improvement at lower per unit cost.

Improve selection for yield of milk and milk components - Within a period of 10 years the average transmitting ability of

bulls to be progeny tested for AI use should be improved from the current level to +1,000 lbs. of milk above the average of the population. By this time, the average PD of bulls in active AI service should be at least +750 lbs. above the population average. Within this period, designed progeny testing schemes permitting the testing of larger numbers of bulls at lower cost and time per bull should be possible. The NCDHIP would include data on economically important milk components in addition to fat. Information on these components would be included in the USDA-DHIA Sire Summaries that would be properly weighted in selection schemes. Research would provide for increases in the accuracy of cow indexing so that cows with high transmitting ability could be accurately identified during the first lactation. Technology should be developed so that expected transmitting ability of offspring from proposed matings could be computer calculated at any time by request.

Identify and genetically evaluates economically important non-yield traits - The technology would include as a first step, the identification of non-yield traits of economic importance, such as those related to reproductive performance, mastitis, growth and milking speed. In addition, certain physiological traits related to hormone and enzyme production, and which might influence either yield or non-yield traits, would be identified (see TO III.1, p 16). Standardized measurement procedures would then be adopted by industry for rating economically important non-yield traits. Procedures would then be implemented to obtain data on these traits through the NCDHIP or by other channels. Large amounts of data would then be available for genetic study. Once sufficient authentic data were obtained, methods would be developed to express genetic merit of economically important non-yield traits in terms usable by industry. Genetic studies would be made on heritabilities, genetic correlations, genetic and phenotypic variation and dollar values. The ultimate technology would be to develop USDA-DHIA Sire Summaries and Cow indexes so that they would include genetic evaluations of yield and non-yield traits based on optimum selection indexes so that maximum genetic progress is being made for total economic worth.

Improve statistical and computer technology - Research attention to improve statistical and computer technology should permit development of systems where equally accurate genetic evaluations can be made from only 1/2 the data currently being used in the development of the sire summaries and cow indexes. This will provide for more efficiency and lower cost. In addition, it will be possible to develop sire summaries to the point where only those bulls with significant new information are considered for each new addition of the summary. It would be very advantageous to dairy producers and other users of the genetic data generated as a result of the NCDHIP if various types of information were readily available to the public on a request basis. This would encourage wider use of the useful information available as a result of the program. Additional research on adaptation of computer technology to these needs would therefore be productive. Technology which would reduce the amount of sorting required during the sire summary and cow index runs would improve the efficiency of the system and reduce costs. Substantial improvement could be made in a relatively few years. To produce accurate and valid genetic data a strenuous effort must be made to eliminate errors from the

system. A joint approach to detecting and eliminating errors must be made by the Dairy Records Processing Centers and USDA. Efforts in this direction should reduce the time spent editing by USDA to only 2/3 of what is presently required. Finally, as automated procedures for acquisition, analysis, and reporting of data are developed, the massive paper work which develops at monthly intervals will be substantially reduced.

Increased Recognition of Genetic Defects and Adverse or Ignored Genetic Effects - Dairy cattle geneticists will give increased attention to defining the degree to which the genetic base is being narrowed. Procedures will be developed to minimize problems which may relate to a narrow genetic base. Such procedures would include calculating inbreeding coefficients of certain mating combinations and estimates of effective population size. Potentially important gene-environment interactions will be defined using herd data from NCDHIP. Once established, these data can be used by dairymen in various geographical areas. An improved identification and reporting system will establish changes in gene frequency of both desirable and deleterious traits on an industry-wide basis. Monitoring of dairy cow production records on a nationwide basis will establish the degree to which inbreeding may counteract selection. From such information, recommendations can be made to dairymen on limitations of inbreeding. Additional research attention to non-additive genetic effects such as nicking will provide dairy farmers with information on best use of AI bulls and cow families. Accuracy of genetic evaluation will be improved by monitoring changes and effective heritabilities or formation of definable subpopulations. Studies on the beef-producing characteristics of AI dairy bulls will permit animal producers to choose bulls with best inheritance for beef production. Procedures will be developed to identify cows and bulls whose progeny will maximize yield and profitability using a minimum of concentrate feeds.

C Research Approaches

1 Improve selection for yield of milk and milk components.

a Continue and strengthen research support for national genetic evaluation programs capable of monitoring genetic and environmental changes in the dairy cattle population and incorporating appropriate improvements into sire summary procedures on a timely basis. (NER Beltsville, MD)

b Identify important sources of genetic and environmental variation that affect cows records and information on relatives and develop procedures to account for these sources of variation in order to materially increase the accuracy of Cow Indexing Procedures. (NER, Beltsville, MD)

c Develop improved methods of pedigree evaluation to increase the accuracy of selection of bulls for progeny testing.

d Maximize the accuracy of genetic evaluations based on part records by identifying and accounting for genetic and environmental influences and developing more accurate projection factors. (NER, Beltsville, MD)

e Develop and implement designed progeny testing schemes to optimize the time and resources required and the accuracy of progeny testing of bulls. (NER, Beltsville, MD)

f Develop improved data collection and analysis procedures for milk protein and solids through NCDHIP and methods for incorporating these data into USDA genetic evaluations. (NER, Beltsville, MD)

g Acquire computer resources and develop procedures to furnish specific genetic information to the industry on an essentially continuous basis. (NER, Beltsville, MD)

h Utilize records from unofficial NCDHIP testing schemes to increase the pool of current records available for bull and cow evaluation. (None)

i Develop physiological, biochemical and/or cytological approaches to selection which will permit identification of animals with superior genetic characteristics at an early age. (See also TO III.1, p 17). (None)

2 Improve methods for identifying and genetically evaluating economically important non-yield traits.

a Develop uniform industry-wide standards for the measurement of non-yield traits based on realistic appraisals of the genetic and environmental factors affecting each trait. (None)

b Organize methods for obtaining and evaluating economically important non-yield traits nationally including AI stud cooperating herds, NCDHIP and SAES. (None)

c Research the genetic, environmental and economic aspects of appropriate non-yield traits to provide information for within-herd improvement in NCDHIP and information for USDA genetic evaluation of these traits. (NER, Beltsville, MD; SR, Lewisburg, TN; WR, Logan, UT)

d Develop procedures for transmitting non-yield data from dairy records processing centers to USDA and for editing and file updating of non-yield traits in USDA genetic evaluation system. (None)

e Develop useable and understandable methods for expressing genetic merit of individual non-yield traits. (NER, Beltsville, MD)

f Develop genetic economic indexes that include yield and non-yield traits for the overall evaluation of bulls and cows when different degrees of emphasis are permitted for different herds or regions. (None)

3 Develop improved statistical and computer technology.

a Develop procedures for screening and selection of input data so that only those data needed to increase accuracy are used in USDA genetic evaluations. (None)

b Evaluate linear model procedures for Sire Summaries and Cow Indexes especially for increased accuracy and decreased computer costs. (NER, Beltsville, MD)

c Develop on-line or real-time data access procedures so industry can request specific data on a timely basis. (None)

d Develop improved procedures for the dissemination of USDA genetic information on an industry-wide basis, in terms of timeliness and scope. (NER, Beltsville, MD)

e Develop computer procedures to decrease the need for expensive re-sequencing of data during Sire Summary and Cow Index runs. (None)

f Develop procedures coordinated with the dairy records processing centers to increase the efficiency and effectiveness of editing and data correction procedures, thereby decreasing USDA's editing costs. (NER, Beltsville, MD)

g Develop pseudo real-time procedures for acquisition and transmittal of information between farms, dairy records processing centers and USDA. (None)

4 Develop improved methods to recognize genetic defects, adverse effects of current selection procedures, and to utilize economically important effects and traits now overlooked.

a Determine degree to which the genetic base of each breed is being narrowed and inbreeding is increasing, including degree to which this is likely to happen in the future, and devise methods for minimizing the genetic dangers. (None)

b Determine if gene-environment interactions, such as between temperament and herd management regime, are becoming important at higher production levels so more definitive recommendations for individual matings can be made to dairymen. (WR, Logan, UT)

c Determine if detectable changes in gene frequency are occurring that can be utilized (increased if desirable or controlled if deleterious) especially regarding conformation, behavioral and physiological traits. (None)

d Determine to what degree is inbreeding a problem on a within-herd basis that may be counteracting selection especially due to lack of cow identification. (None)

e Determine if non-additive genetic effects are significant in bull progeny groups so that specific recommendations can be made on a sound basis for mating bull and cow families. (None)

f Determine if there are different effective genetic or environmental parameters by region, breed, etc., that can be accounted for to increase the accuracy of genetic evaluations. (None)

g Determine degree to which beef characteristics of dairy bulls can be measured or selected for, without interfering with genetic progress that is of paramount importance to the dairy industry. (NER, Beltsville, MD)

h Determine if cows and AI bulls can be categorized on ability to fulfill nutritional requirements from high yield with roughage instead of concentrates and identify those with desirable characteristics. (WR, Logan, UT)

D Consequences of Visualized Technology

1 Increase income of dairymen.

2 Decrease number of cows needed to produce given amount of milk.

3 Require higher level of management on farm to realize cows' genetic potential for yield.

4 Increase individual cow problems due to stress of high yield.

5 Increase value of NCDHIP to dairymen.

6 Increase effectiveness of within-herd selection by dairymen.

7 Increase effectiveness of breed association programs for breed improvement.

8 Provide even more valuable educational material for Extension and academic teaching.

9 Make dairymen more conscious of the importance of certain traits to the profitability of their herd.

10 Lengthen productive life of cows.

11 Make the show ring more meaningful for animal improvement.

12 Increase market for U.S. bull semen and live animals in foreign countries.

13 Carry over computer efficiency into genetic improvement programs for other species.

14 Reduce hand recording required in NCDHIP at farm level.

15 Increase (or decrease) value of individual animals, lines, or families due to presence of particularly desirable (or undesirable) genes or gene frequencies.

16 Increase emphasis on (a) avoidance of inbreeding, and (b) use of bulls on the basis of desirable "nicking" situations and presence of desirable beef characteristics.

E Potential Benefits

The following statistics were used and assumptions were made in calculating the potential benefits from improved genetic capacity for production:

Milk cows -	11.2 million
Milk price -	\$8.20/cwt/3.5% fat milk with 8¢ fat differential
Cows bred by AI bulls -	6.6 million
Cows bred by non-AI bulls -	4.6 million
Extra income over feed cost/100 lb of PD of sire -	\$4.75
Increased use of high PD bulls over average PD bulls	+50%
Percent average PD of non-AI bulls is of effective PD of AI bulls	50%
No. of dairy farms	180,000
Average dairy herd size	60
Cost to raise calf from birth until first calving	\$400
Salvage value of mature cow	\$300

The current situation and the visualized gains arising from new technology are shown in III.3 A and B. Details of the stepwise calculation of potential benefits are shown in the Appendix, pages 80 to 85 .

Potential Benefits in 1985 from Research to Improve Genetic Capacity for Production

Item	Extent of Improvement	Value in 1985 Million \$
Increased genetic improvement shown by improved Predicted Difference of bulls	From +64 lb. to + 113 (increase of 49 lb)	150
Reduced cow replacement rate	30% to 24% (Improvement of 20%)	26
Lowered veterinary costs	\$5 per cow	20
Reduce losses of high producing cows	+100 lb milk/cow	33
Improved statistical and computer technology[1]		
Recognition of genetic defects[1]		
Recognition of adverse or ignored genetic effects[1]		
		229

[1]Items could have significant potential benefit but \$ value is difficult to assess.

F Research Effort[1]

	Year	Current SY's[2]	Support[2] Gross Dollars X 000	Expanded Support SY's (ARS Only)
ARS	1975	6.8	774	9.8
SAES	1975	23.9	2,631	
Others	Not available			
Total		30.7	3,405	9.8

Years required for ARS and related SAES to achieve Visualized Technology 10

[1]From Inventory of Agricultural Research, FY 1975, Vol I, CSRS, USDA, March 1976

[2]Total SY's in RPA 311 (Biological Efficiency) Field of Science 0510 (Genetics and Breeding), Commodity 3100 (Dairy Cattle)

III.4 Improve Management Practice and Systems (This TO is related to and will be closely coordinated with all other TO's in this NRP and with NRP's 20400 Livestock Structures and Equipment; 20420 Disease Control - Cattle; 20100 Forage Crops Production; 20520 Processing Field Crops; 20530 Technologies for Food and Feed Uses - Animal Products; and 20790 Preventing Pollution of and Improving the Quality of Soil, Water and Air).

A Current Technology

Substantial changes have occurred in dairy herd management practices and systems since 1950. One of the major changes is in herd size. In the dairy enterprise as in many others, there are economies associated with size. Because of significant improvements in equipment and buildings associated with the dairy enterprise, dairy farmers can now manage a larger herd than was possible previously. Average herd size of cows on DHIA test has increased from 30 to 60 in the period since 1950. The degree to which herd size has increased varies markedly between areas of the country. Herd size is at a maximum in California, Arizona and Florida. In several other major dairy areas, herds are much smaller and herd management practices have not changed as drastically.

Large herds demand more management skills than small herds. Some dairymen who have been successful managing herds of 30 to 50 cows fail when herd size is increased. Dairymen who are sufficiently well organized and equipped to provide for the needs of individual cows within a herd are usually successful. More research attention should be given to the various facets of herd management if dairy enterprise failures are to be reduced. Even though the national trend is toward larger dairy herds, many herds of moderate size continue to produce milk. The problems related to efficient management of average-sized herds must continually be researched.

The trend toward larger herds has caused many dairymen to move toward dry-lot, stored-forage feeding. Even though nutrient losses are sustained in harvesting a green crop as hay or silage, owners of large herds feel that the gains in feed handling and feeding offset these losses. Lowered availability of and higher prices for fossil fuel may necessitate a further critical look at this trend and some dairymen may need to consider more use of pastures, particularly with small herds or with part of the cows in large herds.

High-producing cows under loose housing conditions and milked in a parlor are seldom in the parlor for sufficiently long periods of time to eat enough grain to meet their energy needs for milk production. To correct this situation, cows in large herds are frequently grouped according to production level and fed additional concentrates in the barn lot. It is becoming more common to mix roughages and concentrates together in one complete feed with the proportion of concentrates higher in the lots with groups of high-producing cows. A silage-concentrate mixture is particularly common.

A large proportion of the labor involved in a dairy enterprise is used during the time cows are milked. Revolutionary changes have been made in the systems by which cows are milked. A major change since 1950 has been in the advent of milking parlors where only a small portion of the

herd is housed at any one time during milking hours. Various types of milking parlors have been designed and each system has its proponents. Most popular in many areas are the double herringbone type, usually six to 12 cows on each side. However, carousel and more recently, polygonal parlors have been designed which have certain advantages.

Milking machines now in use do not always milk cows with maximum speed and with minimum injury to the udder. Sometimes the problem is improper use and/or inadequate maintenance. Twice daily milking has generally been accepted as the most profitable milking system for most dairy herds. However, some dairymen are experimenting with milking high producing cows three times daily and have found that increased milk production offsets the added labor costs involved in milking. Milk production levels and labor and feed costs when cows of various production levels are milked more than twice daily have not been established.

As dairy herds become larger, as more herds are concentrated in a given geographical area, as human population density increases in areas where dairy enterprises are common, as citizens become more aware and concerned about their environment, and as laws are passed and enforced which set certain specified controls on air and water composition and quality, the disposal of excreta from dairy cattle looms as an increasingly significant problem. Research and experience have provided some answers in recent years, but many problems remain to be solved.

An increase in herd size is often accompanied by an increase in calf mortality. With calf losses averaging 15 percent and with the average herd life of a cow slightly over three lactations, a dairyman has barely enough replacements to maintain herd size. It is essential to have a high percentage of healthy replacements if animal quality within dairy herds is to continue to progress.

Revolutionary changes have occurred in dairy cattle housing. Where at one time most of the Nation's dairy herd was housed and milked in conventional stanchion barns, other forms of housing have tended to become more popular. particularly in some sections of the country. Loose housing systems, where dairy animals rest and eat between milkings have become more popular and, more recently, many herds, particularly those of considerable size, are maintained under free stall housing conditions where each cow has access to a stall to use between milkings. Because they offer advantages in terms of cow comfort, cleanliness, and freedom from injury, and because of appreciable reduction in bedding use, free stalls have become popular, but at the same time, their use has created materials handling and other types of problems. The manure voided by cows housed in free stalls is uncontaminated with bedding and is therefore quite fluid in its physical characteristics. Thus, new systems need to be devised and additional research attention needs to be given to manure handling under free stall housing conditions. In addition, answers are needed on stall construction, size, floor surfaces and bedding needs in free stall systems. Housing systems which provide for environmental control but still allow labor efficiences need to be designed for areas with extreme hot or cold climates.

Specific characteristics of current dairy herd management practices are indicated in the subsequent paragraphs. Some of these characteristics have been mentioned in previous Technological Objectives of this National Research Plan, and also, in some cases, in other National Research Plans.

Current Herd Management Systems- In general, dairy herd management programs provide for 12- to 13-month calving intervals with a 60-day dry period and rebreeding beginning 60 days after calving. While there is wide variation between dairy farmers, current cow handling, milking and feeding systems discourage individual attention to cows. In an attempt to provide more uniform attention to cows of a similar production level, many dairymen divide a herd into several groups. Inadequate information is available on most desirable group size and on animal behavior in response to changes in grouping. In many herds, good cows are underfed and poor cows are overfed (See TO III.2, pages 21 and 23). Relatively little attention is directed to the nutrition and exercise needs of dry cows. Some cows in estrus are not detected. (See TO III.1, pages 10 and 12). Culling and mating decisions frequently are based on inadequate information and are time consuming. (See TO III.3, page 29). Too frequently, animals are not properly identified and records on individual cows are not sufficiently systematized for effective herd management. While one can point to excellent dairy operators, many dairy managers have only limited knowledge and training in personnel management, decision making, economics, and business management.

Labor efficiency in dairy herd management - Labor efficiency is widely variable between herds. Much depends on the herd size, degree of mechanization, housing system and the quality of the labor inputs. Labor required for feeding and bedding is 25 hours and for miscellaneous chores 10 hours per cow per year.

Efficiency and effectiveness of milking systems - (See also NRP 20400). Labor efficiency in the milking operation varies depending on herd size, degree of mechanization and type of milking system. About 25 man hours per cow per year are required for milking. The labor associated with milking can be divided into that required to move cows to and from the milking area, for washing udders and preparing cows for milking, for that associated with the milking act and for post milking activities. While marked progress has been made in milking machine design, milking equipment is not designed for most effective milk removal. Improper milking practices and faulty milking equipment are primary causes of mastitis. (See TO III.6, pages 58 and 59).

Dairy cattle waste management - (See also NRP 20400.) Animal waste cannot be handled in a similar way in all geographical areas. Systems effective in one climate cannot be used in others. Problems exist when animal wastes pollute rivers, lakes and underground water systems. Air pollution is equally troublesome using current animal waste management systems. While animal excreta are a potentially valuable resource, present technology limits animal wastes to use as a

fertilizer. While not a dairy production problem, disposal of milk processing wastes such as whey present a problem when they are discharged in the rivers, lakes and sewage systems.

Rearing dairy herd replacements - Death losses in rearing dairy calves are unusually costly. Average annual death losses in rearing calves to 6 months are about 15 percent. Considerable variation exists between various geographic areas, and between individual farms within areas in the housing, feeding and management practices for rearing dairy calves. Maternity care is often inadequate. Calf diarrhea and respiratory disorders are major problems. (See TO III.6 Page 59 and NRP 20420). Many systems for raising replacements are less than optimum. There is some tendency to neglect yearling heifers because they are not under constant scrutiny and because at that stage of development they are not producing economic returns to the dairyman.

Effects of environmental stress - (See also NRP 20400) Milk is produced in the United States under a wide variety of environmental conditions. Milk production generally declines when atmospheric temperatures are below 40° F. and above 70° F. with the greatest decline at the higher temperatures. High producing cows are affected more by high temperatures than low producing cows and suffer a substantial loss in milk production. High temperatures accompanied by high humidity cause production losses up to 40 percent. High temperatures also lower reproductive efficiency. Heat stress also decreases the efficiency of energy utilization and decreases body weight. Air conditioning and evaporative cooling reduce the effects of heat stress but the former is usually too costly to be practical. The effects of low temperatures on animal performance are not as well documented. However, experience shows that during cold weather, sickness and injuries increase and there is a higher death rate in calves. Under such conditions, rate of gain in growing heifers decreases and milking cows have frozen or chapped udders and teats.

B Visualized Technology

The desired technology for improved dairy herd management practices will be achieved by a systems approach to the operation of the entire dairy enterprise considering all significant factors. Labor efficiency in feeding and caring for dairy animals will be improved. Milking systems that will reduce labor, increase the effectiveness of milk removal and reduce mastitis will be developed. Effective and economical systems of disposing of animal excreta will be developed. Dairy herd replacement losses will be minimized by more adequate feeding, housing and management systems. Cow performance will be improved by minimizing stress. To accomplish the desired technology there must be considerable support from a wide variety of research areas including engineering, economics and animal disease. Following are specific goals toward which substantial progress is expected as a result of research on dairy management:

Improve dairy management systems - In the near future, many dairymen will be using feeding systems where complete feeds are fed and cows are grouped so that energy intake is consistent with levels of milk production. (See also TO III.2, Page 26). Cow grouping and impacts of changes of cows between groups will be well understood. Another advanced method used by dairymen to feed cows more efficiently will be regulation of concentrate intake by electronic means in accordance with nutrient needs for milk production, (See also NRP 20400). Estrus will be more readily detected by external devices measuring physical activity or by chemical examination of milk or body fluids (see also TO III.1, Page 15). Automated animal identification (see also NRP 20400), and herd record keeping systems will permit rapid and easy retrieval of feeding, breeding, reproduction and health information. In some important dairy areas, herd size may not increase sufficiently to justify expenditures for sophisticated electronic equipment. Nevertheless, decreases in chore time and increased management efficiency can be accomplished by other means and are an appropriate subject for research. Cows will be in a more desirable physical condition for calving, lactating and reproducing, by providing adequate exercise and proper nutrition during the dry period, (See also TO III.2, Page 23). Optimum calving intervals for greatest economic returns will be achieved by altering the length of the dry periods and/or the period from calving to first breeding. By research on dairy management systems and by appropriate training, dairy managers will be able to make wise business and herd management decisions and do a better job of training and handling personnel in their employ.

Increase labor efficiency in dairy herd management. See also NRP 20400. Much of the improvement in reducing labor needed for dairy herd management will be achieved by additional automation and by the alteration of housing and cow handling systems. It is expected that additional research by both public employees and industry will result in the development of new automated feeding systems to complement and supplement those already available. The development of self feeding programs and the use of mechanically fed complete feeds will reduce labor needs. This may involve some alteration in the physical form of feeds which are now ordinarily fed. An improved design and construction of housing for young and mature stock will reduce labor in feeding, bedding and waste handling. (See NRP 20400). A thorough study of labor requirements for dairy farm chores in herds of different sizes and for various housing and management systems will permit adapting the most efficient systems to other management conditions. Thorough study and subsequent implementation should reduce labor required for feeding and bedding to 19 hours per cow per year and miscellaneous chores to 8 hours per cow per year. More information on personnel management techniques will develop the dairyman's ability to recruit dairy farm employees and handle dairy farm labor more effectively.

Increase the efficiency and effectiveness of milking systems. (See also NRP 20400) - Within 10 years it is reasonable to expect that automated milking equipment will reduce labor required for milking by 25 percent. Improved cow traffic patterns and automated gates will reduce labor required for moving cattle to and from milking parlors by 25 percent. Automated prep stalls will reduce labor for preparing cows for milking by 25 percent. The design of milking equipment will improve the effectiveness of milk removal by 10 percent. Finally,

improved milking practices and systems for maintaining milking equipment in proper order will reduce mastitis incidence by 20 percent (see TO III.6, Page 64 and NRP 20420).

Improve dairy cattle waste management (See also NRP 20400) - Studies under a wide variety of geographic and climatic conditions will permit the development of effective dairy waste management systems in all areas. Thus, animal wastes will be diverted from water supplies and air pollution will be reduced. New and more effective uses will be developed for animal wastes such as fertilizers, feed, bedding, fuel and certain other industrial uses. Milk processing wastes will be diverted to other uses such as cattle feed or human food, so that they will be considered a valuable resource rather than an unwanted waste.

Lower dairy herd replacement losses - Within 10 years facilities for and care of gestating and parturient cows will be improved to reduce the number of calves born dead and to get newborn calves off to a better start. Effective calf housing, feeding and management systems will be developed for all climatic conditions and herd sizes. Management systems and vacancies or medications will reduce calf diarrhea and pneumonia by 50 percent. Feeding and management systems will be improved so that replacement heifers can be raised at optimum growth rates. The effect of these technological advances will be to reduce dairy herd replacement heifer losses to 8 percent.

Reduce effects of environmental stress - (See NRP 20400) The development of improved technology to reduce effects of environmental stress on dairy cattle performance will be particularly important in those areas of the United States where climatic stress is severe. Milk production per cow will be improved appreciably. Appropriate environmental control methods will reduce the milk production decreases resulting from heat stress and also the reductions associated with a combination of heat stress and high humidity by 2.5 percent. Losses in reproduction caused by high temperatures and humidity will also be reduced by 25 percent. Environmental control will increase milk production levels in cold climates by 1 percent.

C Research Approaches

The development of improved technology in dairy herd and dairy farm management must have research inputs from several disciplines and fields of science. It is particularly important that research in this area be well conceived and that inputs be sought from a wide variety of competent individuals. Constant inputs from those with an excellent background in dairy herd management are important. (See TO III.1, III.2, III.3, III.6 and NRP 20400, 20420, 20100, 20520, 20530 and 20790.)

1. Develop herd management systems designed to secure maximum efficient production per cow.

a Develop electronic transmitting and sensing devices which can be implanted in animals to provide permanent identification and physiological data transmission for automated data collection systems.(None) (See NRP 20400)

b Develop record keeping systems using computers to automate records, provide for rapid information retrieval and analysis, and permit management by exception. (NER, Beltsville, MD) (See NRP 20400).

c Develop systems for indivualized feeding of concentrates to high producers using electronic equipment. (See NRP 20400) (WR, Logan, UT)

d Develop improved methods of formulating and presenting complete feeds to groups of dairy cattle. (See also TO III.2, Page 26 and NRP 20400). (NER, Beltsville, MD; SR, Lewisburg, TN)

e Identify management practices which will aid in effective heat detection and optimum calving intervals. (NER, Beltsville,MD)

f Determine optimum herd and group sizes and systems for grouping cows to achieve highest production with greatest labor efficiency. (None)

g Identify the importance of social behavior of cows as related to grouping and subsequent cow performance. (NER, Beltsville, MD; WR, Logan, UT)

h Evaluate the influence of exercise on ease of calving, efficiency of utilization of feed energy for milk production, and on reproductive efficiency. (WR, Logan, UT)

i Determine optimum combination of lengths of lactation, dry period, and days open for most economical production. (NER, Beltsville, MD; WR, Logan, UT)

j Study personnel training and management programs in successful large dairy operations and develop guidelines for personnel management for various herd sizes. (None)

2 Improve labor efficiency in feeding and caring for dairy animals.

a Develop automated systems for feeding which reduce labor input. (None) (See NRP 20400)

b Develop self feeding systems for forage to reduce labor. (NER, Beltsville, MD) (See NRP 20400)

c Study the use of complete feeds fed mechanically to cows in groups. (None) (See NRP 20400)

d Develop bedding replacements which minimize need for conventional bedding material. (NER, Beltsville, MD)

e Improve design and construction of housing for young and mature stock to reduce labor in feeding, bedding and waste handling. (None) (See NRP 20400)

f Develop dairymen's ability to handle labor effectively. (None)

g Develop screening criteria for potential dairy workers. (None)

h Study total labor requirements for feeding, bedding, and other chores for various herd sizes and for various housing and management systems, and develop ways of adapting the most efficient systems to other management conditions. (None)

3 Develop milking systems that will reduce labor, increase effectiveness of milk removal and reduce mastitis.

a Develop methods to improve efficiency of milking systems, including cow movement, cow preparation, and automatic machine removal. (NER, Beltsville, MD) (See NRP 20400)

b Study and compare various types of milking parlors, parlor layouts, and types of milking equipment to determine most efficient operation for herds of varying sizes. (None) (See NRP 20400)

c Determine the effect of milking machine disorders on the incidence of mastitis. (NER, Beltsville, MD) (See TO III.6, Page 64, and NRP 20420)

d Redesign milking equipment to improve effectiveness of milk removal and to reduce injury to the udder and consequently reduce mastitis. (NER, Beltsville, MD) (See NRP 20400)

e Study milking practices to find ways of reducing udder injury and mastitis. (NER, Beltsville, MD)

f Determine if increased frequency of milking would result in higher total yields from high producing as compared to average producing cows. (NER, Beltsville, MD)

4 Develop effective and economical waste management systems. (None) (See NRP 20400)

a Determine the optimum and maximum loading rates of manure on the land as governed by environmental factors of the locality. (None) (See NRP 20400 and 20790)

b Develop and evaluate methods for satisfactory waste disposal by conversion to a salable commodity. (NER, Beltsville, MD) (See TO III.2 and NRP 20400)

c Determine the nutritional value of dairy cattle manure as an animal feed. (NER, Beltsville, MD) (See TO III.2, Page 23 and NRP 20400)

d Develop efficient methods of separating solid and liquid wastes so solid portions can be used for feed, bedding, etc. (None) (See NRP 20400)

e Study the use of solar energy for drying animal wastes. (None) (See NRP 20400)

f Establish methods of manure use in the cultivation of microorganisms and lower animals. (None) (See NRP 20400)

Evaluate present disposal techniques to determine the effectiveness in reducing pollution. (See NRP's 20400 and 20790) (SR, Lewisburg, TN)

h Study alternative waste disposal methods to find the optimum system under various climatic conditions. (None) (See NRP's 20400 and 20790)

i Study use of milk processing wastes as animal feed. (None) (See NRP 20530)

5 Develop management practices to reduce calf losses, improve the raising of dairy replacements, and increase returns from sale of surplus stock.

a Develop housing and management systems for maternity care so that calves will be born under more sanitary conditions. (None)

b Study systems to provide for closer monitoring of calving, including closed circuit TV for monitoring and synchronized breeding and induced parturition for timing calving when help will be available. (None)

c Study calf feeding systems, including types, amounts, and conditions of feeds, frequency of feeding, and length of milk feeding period for optimum growth rate, least cost, and greatest labor efficiency under various herd size and climatic conditions. (None) (See also TO III.2, Page 26)

d Study calf housing systems to determine optimum conditions for effectively raising calves in different climates. (None) (See NRP 20400)

e Develop systems for fitting dairy beef production into overall dairy production schemes.

f Identify management practices which result in healthy calves grown at optimum rates with lowest feed and labor costs. (NER, Beltsville, MD; WR, Logan, UT)

g Identify feeding and management practices which result in optimal growth rates for replacement heifers from weaning to freshening. (None)

6 Reduce adverse effects of environmental stress on dairy cattle.

a Study the economics of evaporative cooling and mechanical air conditions in hog climates. (None) (See NRP 20400)

b Develop methods of cooling animals that are economical in hot humid climates. (None) (See NRP 20400)

c Study management systems that will reduce the effect of high temperature and humidity stress. (None)

d Develop physiological measurements that can be used to predict when cows are reaching stress thresholds so that management and/or housing changes can be made before production and/or reproduction losses occur. (None)

e Study the effects of cold stress on production, reproduction, feed efficiency, growth, and health of dairy animals. (None)

f Develop economical environmentally controlled housing to reduce cold stress in dairy animals. (None) (See NRP 20400)

g Study management systems that can alleviate cold stressful conditions. (None)

D Consequences of Visualized Technology

1 Automated and more accurate feeding systems increase milk production and decrease milk cost.

2 Better estrus detection shortens calving interval.

3 Improved herd record keeping systems increase milk production and reduce labor.

4 Optimum grouping to reduce social stress increases milk production.

5 Increased labor efficiency, reduces labor inputs, permits low cost expansion of dairy farm units, reduces costs of milk production and reduces consumer costs.

6 Improved milking practices reduce labor and lower production costs.

7 Improved milking equipment speeds up milk removal and improves udder health.

8 Improved milk quality increases consumer acceptability and milk consumption.

9 Reduce water and air pollution by animal wastes.

10 Lower animal waste disposal costs reduce milk production costs.

11 New uses of animal wastes save natural resources.

12 Improved calf rearing practices reduce veterinary costs and calf losses.

13 Replacement heifers grow more efficiently at lower costs and enter milking herd earlier.

14 Advances in environmental control improve milk production, reproductive efficiency and feed efficiency.

E Potential Benefits

In calculating the total potential benefits from the Visualized Technology certain statistics have been used and assumptions have been made concerning the current situation as follows:

Milk cows	11.2 million
Milk production	115 billion lbs.
Concentrates consumed/cow/yr	4300 lb.
Concentrate price	$130/ton
Milk price	$8.20/cwt
Current annual calf losses	15%
Labor costs	$2.00/hr
Replacement heifer rearing costs (Ave. cost per month to 24 months)	$16.67/mo.

Details of the calculations used in arriving at the values shown in the table below are shown in the Appendix, pages 86 to 88.

Potential Benefits in 1985 from Research to Improve Management Practices and Systems.

Item	Extent of Improvement	Value in 1985 Million $
Better feeding systems (See TO III.2)		
Improved milk production		
Decreased feed cost		
Better herd records		
Increased milk production	2.5%	236
Reduced labor	1 hr/cow/yr	23
Optimum herd grouping		
Increased milk production	1%	53
Reduced labor for dairy chores	8.75 hrs/cow/yr	196
Reduced labor for milking	6.25 hrs/cow/yr	140
Reduced death loss of replacement heifers	7% reduction	16
Reduced costs for treating sick calves	$4/calf	18
Replacement heifers enter herd earlier	1 month earlier	57
Improved environmental control		
Reduction in heat stress in South (Improved milk production)	2.5	41
Reduction in cold stress in North (Improved milk production	1%	21
Total		801

F Research Effort[1]

	Year	Current SY's[2]	Support Gross Dollars[2] X 000	Expanded Support SY's (ARS Only)
ARS	1975	2.1	324	5.1
SAES	1975	24.3	2,061	
Others	Not available			
Total		26.4	2,385	5.1

Years required for ARS and related SAES to achieve Visualized Technology 10

[1]From Inventory of Agricultural Research, FY 1975, Vol I, CSRS, USDA, March 1976

[2]Represents total SY's and $ in RPA's 312 (Environmental Stress) and 313 (Production Management Systems)

III.5 Improve Efficiency of Producing Quality Products

(This NRP is closely related to NRP 20530, Processing Animals and Animal Products and to NRP 20600, Marketing Livestock and Animal Products).

A Current Technology

There have been steady and significant changes in consumer preferences for milk and milk products, but production practices within the dairy industry have not been altered wholly in accord with these trends. There has been a steady decline in per capita consumption of milk and dairy products, dropping from 706 (lbs. milk equivalent) in 1955 to 543 in 1974. Within the total consumption, there have been marked shifts in amounts of milk and the various dairy products. Most products that are primarily fat or high in fat have suffered drastic declines. Butter consumption has dropped by over 50 percent since 1950, while low-fat fluid milk has increased over 500 percent from 1950 to 1974. Cottage cheese consumption has increased 52 percent since 1950. More recently, other cheeses have also greatly increased in sales. In 1963, cheese represented only 13 percent of milk product sales; it now makes up 22 percent. Looking at the total picture, it appears that per capita consumption of non-fat constituents of milk has remained fairly steady over the last 20 years, while the total drop in consumption arises almost exclusively from whole milk and butter.

Agricultural research needs to take this changing consumer preference into account in order to supply future needs. This will also benefit dairymen by channeling production resources into providing food which has a favorable future prognosis for increasing consumption and sales. Production research also needs to explore other ways of making milk and dairy products more acceptable, such as by modifying or changing the nature or ratios of certain components and by eliminating losses due to milk not being accepted by processors. Such product-quality research must involve dairy technology, economics, genetics, nutrition, management and physiology.

For the benefit of both consumers and dairymen, research objectives must be formulated with a realistic appraisal of the role of milk and dairy products in the American diet, with emphasis on their unique values and characteristics. The unique contribution of milk is in supplying minerals, vitamins, and protein. Milk protein, composed of casein, lactalbumins, and lacto-globulins, is an excellent source of all the amino acids essential to human health. In addition, with adequate attention to maintaining product quality, milk and dairy products are more palatable than most dietary alternatives. Also, milk protein is cheaper than most alternative animal proteins.

On the other hand, aspects of milk which are declining in desirability to the consumer should be de-emphasized if it is not feasible to increase their acceptance through new technology. Chief among these is milk fat. The dietary fat-heart disease controversy has further reinforced an already declining butterfat consumption pattern, so that even at equal prices, vegetable fat may be preferred by an increasingly diet-conscious public. Production of lactose is also in an unfavorable climate, due to heightened awareness of lactose intolerance.

Therefore, it is clear that technology in the industry should be geared to supplying what consumers most need and want, which is primarily the high-quality, palatable protein found in milk and dairy products. Processing practices are capable of altering the content of some components of milk, but they cannot produce additional amounts of milk protein.

Current milk protein production is estimated as 3,751 million pounds annually. It is believed that with a modest research effort, information can be garnered to assist in increasing milk protein production by 1985 to levels greater than would occur through current practices, which consider yield of milk and percentage fat composition, but with no attention to protein. If pricing systems are also changed, still greater incentive for increases in protein would be obtained.

Current production practices in the dairy industry are not specifically geared to the production of protein. Milk yield and percent butterfat are the two primary criteria which receive attention, both from genetic and management standpoints. This anachronistic situation arises primarily from a pricing system which rarely considers any component other than fat. Current production recommendations to dairymen center on increasing total volume of milk, irrespective of its composition. There has been no concentrated effort to develop optimum goals for milk composition or relative amounts of components to be produced. Current milk composition is approximately 3.7 percent fat and 3.25 percent protein. While some information is available to establish technology for attaining production goals, no progress can be made until research formulates these optimum national objectives. This needs to be done for not only the current economic conditions but for alternative conditions that might develop in the future.

Specifications

1. Per capita consumption	540 lbs. fluid milk equiv./year
2. Production of protein per cow	324 lbs/year
3. Number of milk cows	11.2 million
4. Total milk protein produced	3,751 million lbs.
5. Milk arriving at plants sometimes contains undesirable flavors and odors that reduce desirability and amount of products	Exact estimates are unavailable
6. Unknown causes result in the production of milk which is unacceptable by legal standards of composition, adulteration, etc.	Exact figures are unavailable

B Visualized Technology

A team research approach would be made to establishing the economically optimum type and quality of milk to be produced by the nation's dairymen. This effort would focus on the various milk components and their true market value, taking into account long-standing trends in consumer preference. In addition, major variations between milk markets (fluid milk versus manufacturing) would be considered. Also, existing legal barriers to changing milk composition would be taken into account. In this way, information would be obtained to advise dairymen and production industry personnel on the optimum goals for milk composition.

Also considered would be an optimum ideal national strategy for milk composition, ignoring present barriers such as legal restrictions and current pricing systems. A comparison of optimum consumer versus optimum producer-economic milk composition goals should be informative, and may generate movement toward more realistic legal and economic criteria. Evidence suggests that optimum national goals will be to maximize production to some degree. This will require genetic selection to bring about, due to the positive relation between fat and protein. However, wide species differences in the ratio of protein to fat indicate that this is feasible.

Production research related to energy considerations in milk production is now needed. As the percent solids in milk decreases, the percent water increases, thus requiring greater transport and handling energy than if the same amount of solids were in more concentrated form. Economic consideration of this problem needs to take into account pricing systems which may favor lower percent solids (systems aimed at fluid milk markets). Also to be considered is the optimum distribution of milk energy between the production of fat and protein.

A moderate level of research dealing with other aspects of milk composition and quality is needed. Some work is already underway on increasing the polyunsaturated fatty acid composition of milk fat by feeding methods. Knowledge of the extent to which cows differ genetically in composition of milk secreted would be useful basic information. In such research, the alternative possibilities of alterations during processing must be considered.

Specifications

1. Per capita consumption	505 lbs. fluid milk equiv./year
2. Annual production of protein per cow	370 lbs.
3. Number of milk cows (in 1985)	10.91 million
4. Total milk protein produced	4,036 million lbs./year

5. Milk arriving at plants sometimes contains undesirable flavors and odors that reduce desirability and amount of products — gains not estimated

6. Unknown causes result in the production of milk which is unacceptable by legal standards — gains not estimated

C Research Approaches

The research approaches will involve the disciplines of economics, genetics, nutrition, physiology and management.

1 Increase the production and efficiency of production of milk protein: (None, all items under this heading)

a Study the relative values of each of the components of milk as related to economic conditions.

b Calculate the cost in monetary and energy terms of producing the various components of milk.

c Determine the optimum proportions of the various components of milk under varying economic conditions.

d Assuming a national goal of increasing protein production and decreasing fat production, establish the optimum proportions of the various components of milk.

e Study the role of genetic selection in attaining specified goals for the desired production of milk components.

f Study the role of feeding and management in attaining specific goals for the desired production of milk components.

g Consider changes in milk pricing systems which would encourage efficient production of the desired components of milk.

h Determine if the theoretical increased energy efficiency of producing milk with lower fat and higher protein can be achieved at an economic advantage.

2 Increase the suitability and acceptability of milk for various uses:

a Ascertain if certain combinations and proportions of milk constituents are more suitable for certain purposes than others. (None)

b Determine which production practices cause objectionable flavors and odors in milk. (None)

c Study genetic and management factors which are involved in determining the relative proportions of casein and whey proteins in milk. (None)

d Develop farm milk handling procedures which can be altered to improve product quality. (None)

3 Improve the flavor and odor of milk arriving at milk plants: (None, for all items under this heading)

a Study how farm milk-handling procedures can be altered to improve product quality.

b Identify feeding practices which can be altered to favorably affect milk flavor.

c Consider the effect of other management and environmental factors on milk flavor.

d Determine if milk flavor is influenced genetically, other than through major components.

4 Reduce the proportion of milk produced that fails to meet accepted legal standards: (None, for all items under this heading)

a Study nutritional factors which are responsible for the production of subnormal milk.

b Identify other environmental factors which adversely affect the composition of milk.

c Determine if selection criteria be altered to decrease the amount of milk that is unacceptable by legal standards.

d Consider if and how legal standards conflict with efficient production.

D Consequences of Visualized Technology

1 Produce more milk protein

2 Lower cost of dairy products to consumers through increased production efficiency.

3 Expand markets for dairy products through production practices.

4 Provide better nutrition in forms attractive to consumers.

5 Decrease excess production of less desirable components, such as fat and lactose.

6 Consumption of alternative forms of protein would decrease.

E Potential Benefits

Because product quality is so closely associated with marketing, no benefits from this TO are claimed in this NRP. Any economic benefits in changed milk composition will be shown in NRP 20600. A calculation showing the benefits of producing more milk protein is shown in the Appendix, pages 87 and 88. However, this $ value is not claimed for this TO.

Potential Benefits in 1985 from Research to Improve the Efficiency of Producing Quality Products:

Item	Extent of Improvement	$ Value in 1985
More milk protein	+14%/cow/yr.	See NRP 20600
Decrease waste milk and increase milk acceptability	not estimated	
Improve milk flavor and odor	not estimated	
Reduce amount of milk below legal standards	not estimated	

F Research Effort[1]

	RPA	Year	Current SY's	Support Gross $ X 000	Expanded Support SY's (ARS Only)
					See NRP 20600
ARS	409	1975	1.8	503	
SAES	409	1975	7.6	564	
Others	Not available				
Total			9.4	1,066	

Years required for ARS and related SAES to achieve Visualized Technology 10

[1]From Inventory of Agricultural Research, FY 1975, Vol I, CSRS, USDA, March 1976

[2]Title of RPA 409 is "Production of Animal Products with Improved "Acceptability."

III.6 Decrease Losses Due to Diseases, Pests and Other Hazards

(See also NRP 20420, Control of Cattle Diseases, infectious, non-infectious, and parasitic; NRP 20480, Control of Insects Affecting Livestock).

A Current Technology

Even under the best management and nutrition conditions, performance of dairy cows is frequently limited by diseases, pests and other hazards. It is quite clear that the incidence of disease is lower when animals are optimally nourished, when stress and injuries are minimized, and when sanitary conditions are maintained.

All diseases pose a threat to dairy farm income. Those which occur as epidemics can cause enterprise failure. At times, entire geographical areas sustain extremely heavy losses. Certain diseases which cause cattle losses also threaten human health. Fortunately, considerable progress has been made in controlling these diseases. While occasional outbreaks occur which are of concern, brucellosis and bovine tuberculosis present considerably less threat both to dairy cattle and humans in the U. S. now than was true in the period prior to the 1940's.

Economically since it affects normal functioning of the mammary gland, mastitis is the most serious disease affecting dairy cattle. It is also a disease in which the incidence is profoundly affected by environment. Therefore, herd management is very significant. Diseases such as paratuberculosis and leptospirosis cause some losses to the dairy industry. Trichomoniasis, vibriosis and vaginitis cause reproduction inefficiency, but losses from these diseases have been reduced with increased use of artificial insemination.

Intestinal and respiratory problems are a serious threat to dairy calves. Mortality among dairy calves is unusually high (See TO III.4). Here again, animal management is extremely important. Many dairymen have reduced calf losses substantially but in other herds losses are catastrophic. Bovine viral diarrhea and infectious bovine rhinotracheitis are examples of diseases affecting many calves. Calf scouts, a general term describing diarrhea, has many causes and is difficult to control and treat.

Dairy cows suffer from two disorders, milk fever and ketosis, which occur much less commonly in other species. Other sources of loss from physiological or metabolic disturbance are grass tetany, bloat, displaced abomasum and the "downer" cow syndrome. Under some circumstances, foot rot is responsible for decreased milk production.

When cattle consume toxic materials in substantial amounts, the effects are both dramatic and catastrophic. Under some circumstances, cows consume such materials as heavy metals, molds, poisonous weeds, nitrates, cyanogenetic plants and toxic chemicals. There are some circumstances under which even though the cow's health seems not to be profoundly affected, the milk is condemned and therefore, unmarketable. (See NRP 20470, Toxicology and Metabolism of Agricultural Chemicals and Poisonous Plants.)

Internal and external parasites cause serious losses, particularly in some areas. Flies are a universal problem, and lice and tick infestation can lower milk production. Internal parasites such as stomach and intestinal parasites, nematodes, lung worms and liver flukes all decrease milk production and growth efficiency.

Most of the information on diseases, pests and other hazards, including Current Technology, Visualized Technology, Research Approaches and Potential Benefits, is discussed more thoroughly in other NRP's under which most of this research is planned and to be conducted. However, certain of the critical diseases deserve some amplification in this NRP since they relate to dairy production practices. This is particularly true of mastitis which is so interrelated with dairy husbandry practices and the milking act that it is discussed in detail in this NRP. A substantial amount of research effort is planned for mastitis within this NRP as well as NRP 20420.

Mastitis in dairy cows - Mastitis causes reduced efficiency and increased costs result from reduced milk yield of infected cows, disposal of unsalable milk, early culling of valuable cows, and treatment. A recent estimate suggests a loss of $69/cow annually. Using this figure the total loss to the U. S. annually would be in excess of $800 million. These losses not only decrease income to dairymen but increase the cost of milk and dairy products to consumers.

Materials used for treatment and prevention of mastitis constitute potential hazards to food safety. Improper use of antibiotics contaminates milk. Surveys indicate that some bulk milk shipments contain detectable amounts of antibiotics. Milk contaminated with antibiotics may result in sensitization of individuals, reactions in hypersensitive persons and the development of bacterial strains which are resistant to antibiotics and which may be harmful to both man and animals. Recent evidence indicates that dipping cows' teats in a germicide after each milking can contribute undesirable residues to market milk. Since this practice is of proven value for mastitis control, altered milking management or new non-toxic products must be devised.

Many microorganisms are implicated and a multitude of environmental and genetic factors influence frequency of infection. Progress in mastitis control can be attained by prevention of new infections, by prompt elimination of infections which do become established, or by reducing the pathological impact of the disease during its presence in the udder. Both basic knowledge and readily applicable management techniques are needed. Avenues that avoid the use of antibiotics need to be pursued.

New Infections - To reduce the rate of new udder infections, dairymen use recommended milking hygiene practices. Teat dipping is one milking hygiene practice which has been demonstrated effective. Various aspects of milking management, machine operation, sanitation and housing have been advocated to control infections.

When a dairyman observes a severe mastitis problem, he may consult a veterinarian, plant fieldman, milking equipment salesman, or extension agent for advice. Bacterial analysis may or may not be obtained. In many cases, dairymen will treat diseased animals with broad-spectrum antibiotics.

Even following treatment, the disease is likely to be present in many cows that fail to exhibit clinical signs. Dry cow therapy regimes are advocated by many. This may involve treating all quarters of all cows as they go dry, or, less likely, all quarters that are positive on bacterial culture. Antibiotic therapy provides only a temporary alleviation of the disease, especially for cows that are inherently more susceptible, and where herd management practices are poor.

Many specific herd management routines, sanitation practices, and milking machine characteristics appear to have a major impact on disease frequency. Modifications of milking machine characteristics may decrease the risk of machine transmission of pathogens. Little research has been conducted in this area.

Coliform mastitis appears to be increasing in importance because coliforms are refractory to antibiotics and to chemicals used in teat dips which are effective against other udder pathogens. Recently, coliform mastitis has been associated with the use of sawdust bedding.

Little is known about increasing mastitis resistance through acquired immunity. Local immunization of the mammary gland may be feasible, but very little information is available about the mechanisms responsible for the increased resistance. Information is lacking on the effect of immunization on levels of serum and milk immunoglobulins and their function in intramammary defense.

No efforts have been made to increase genetic resistance to mastitis, although it appears that there may be a moderate to low degree of genetic variation in mastitis frequency. Mastitis control measures have been incorporated into production testing programs on a very limited basis. Knowledge of the genetic relation between mastitis resistance and milk-producing ability is urgently needed. If higher producers are more susceptible to infection, the problem will become more severe as genetic progress in yield accrues. Very little is known about the underlying defense mechanisms which are responsible for these genetic differences. More information is needed on the role of the teat sphincter, teat keratin, the immune system, hormones, the properties of the leukocyte, and udder size and form.

Established Infection - Dairymen normally detect diseased quarters by gross observation of clotted or bloody milk and marked swelling or soreness of the udder. Such diagnosis is inadequate in that, (1) most infections do not exhibit clinical symptoms at any given time, (2) lack of knowledge of specific pathogens causes the use of combined antibiotics, with the unfavorable results of increasing probabilities of mutation of organisms and contamination of food supply. Treatment of all cows during the dry period has been advocated in heavily infected herds, but means need to be found for more selective dry cow treatment in herds with lower incidence.

Several methods have been advocated as screening procedures for detecting high leukocyte count and consequently, udder infection. All of these tests suffer from several drawbacks, (1) there is an incomplete relation between cell concentration and udder infection, (2) many infections would be missed by screening tests, (3) screening tests are not specific indicators of pathogen identity.

In the treatment of clinical mastitis, the veterinary practitioner must begin immediate therapy. If facilities are available, the clinician may take samples for bacteriological culture and antibiotic sensitivity tests. The resulting information may indicate a need to change therapy and also may provide a basis for prescribing treatment for subsequent infections in that herd.

Inadequate information is available nationally on the distribution of mastitis-causing pathogens. Thus, we do not know whether one organism is gaining importance relative to another. This could be remedied by routine gathering of sterile milk samples and transport to a central laboratory, such as a DHIA laboratory.

Control Programs - The abnormal milk control program of the National Conference on Interstate Milk Shipments is designed to insure that milk from clinically mastitic cows is not added to the milk supply. Abnormal milk is defined as mixed herd milk containing more than 1.5 million somatic cells per ml. Following the lead of most other countries, the prospect in the U.S. is for eventual lowering of the maximum acceptable count to one million, or less. Development of technology for accurate monitoring of milk somatic cell concentration, both manually and electronically, is nearly complete. It must be kept in mind that control of abornmal milk is designed to protect the milk supply from aesthetically objectionable adulterations which adversely affect manufacturing yield and quality. Screening tests of cell concentration used in this program may be too indirect and imprecise to detect infection of specific mammary glands.

Mastitis control programs have been conducted by some States for nearly 30 years. These programs vary and their effectiveness is difficult to assess. Some, such as those in New York and Connecticut, have been specifically aimed at detection and eradication of udder infections caused by Streptococcus agalactiae. These control programs are voluntary in nature, which reduces their impact.

Specifications -- New infection rate for mastitis - Current estimates indicate that there is one new mastitis infection per ten cows per month. One approach to lowering new infections would be to increase resistance through breeding. It is known that resistance to mastitis infection is moderately to lowly heritable, but there is currently no methodology or structure developed for obtaining population data for selection. There is little knowledge of genetic relationships between mastitis and other economic traits nor of anatomical and physiological mechanisms through which genetic variation is expressed.

A second approach to limiting new infections would be to develop effective preventive measures. The influences of specific environmental factors on mastitis incidence are partially understood but possible interactions of factors have not been examined. Many sanitation products are offered with unverified claims, and there are no definitive guides for culling infected cows. While dry cow therapy is widely recommended, there is some lack of conclusive evidence to support the prophylactic value of dry cow treatment. Milking machines, in some cases, are considered to be a causative factor in mastitis incidence, but there are no available machine modifications or options for the reduction of mastitis. While physiological defense mechanisms are recognized as important, there is little knowledge regarding ways of enhancing the phagocytic ability of leukocytes within the mammary gland. Neither are there means of promoting acquired immunity to infection by mastitis pathogens or any other means of artificially enhancing resistance to infection.

Specifications -- Duration of mastitis infection - It is estimated that the duration of the average mastitis infection is 10 weeks. As was the case with new mastitis infections, there is no information to indicate whether genetic resistance may also be expressed by lessening the length of the infective phase within the gland. It is obviously important to be able to detect diseased quarters if a logical basis for treatment is to be undertaken. As was pointed out previously, detection and treatment of mastitis is largely based on clinical symptoms. Hence, causative organisms are not usually known. While screening tests for somatic cell content are available, their value is greatest in routine monitoring of milk quality. In some Dairy Herd Improvement Associations monthly screening tests are made by the supervisor, but in many cases this information is not being effectively used. Laboratory facilities for

Specifications -- Unmarketable milk - It is estimated that .5% of the milk produced is unmarketable because of milk contamination with antibiotics or because of high leukocyte count. Currently bulk tank milk is rejected if the somatic cell count exceeds 1.5 million. No definition of abnormal milk based on somatic cell concentrations can be justified objectively. The present limits were set to minimize disruption of national milk supplies and is likely to be lowered. Any new lower limit must take into account the natural protective role of the leukocyte, and factors other than infection which may affect cell counts. In the case of milk contamination with antibiotics, withdrawal times must be followed for antibiotics used prior to and including milk in bulk tank shipment. Withdrawal times must also be followed for the sale of cull cows treated with antibiotics. However, the withdrawal time varies for various tissues and organs and definitive information on this point is lacking. Little information is available on the frequency of milk supply contamination with teat dips.

Economic Specifications -- Mastitis - It is estimated that the milk production not realized because of mastitis amounts to approximately 5 percent of the total milk supply. The milk voluntarily discarded because it is abnormal due to mastitis or because of recent antibiotic therapy is estimated at one percent of the total supply. The cost of therapeutic drugs and veterinary services associated with mastitis are estimated at $6.00/cow/yr. The animal losses due to early culling or death of infected cows are about 2 1/2 percent of the cows/year. The potential loss caused because dairymen are prohibited from marketing milk which is mastitic or contains excessivly high levels of antibiotics is estimated at 0.5 percent of the total supply.

Metabolic disorders in dairy cows. (See NRP 20420) - Milk fever (parturient paresis) is a metabolic disorder afflicting parturient cows. It is characterized by a dramatic lowering of blood serum calcium. In some herds, as many as 30 percent of the susceptible cows (third and subsequent lactation) develop milk fever. Mortality is high in untreated cows but treatment by injection with calcium borogluconate is relatively simple and is highly effective for most cows. Preventive measures include controlling the calcium level of the feed during the prepartal period and feeding vitamin D metabolites prior to calving. Losses from milk fever are not extensive but are of sufficient magnitude to justify continued research effort.

Ketosis is a metabolic disorder occurring most frequently during the two-month period immediately following calving. It affects high-producing cows and is very costly because of its substantially depressing effect on milk production. When ketosis occurs, cows have a depressed blood glucose and an increased level of blood ketones. Because some ketones are excreted in the milk, milk quality can be adversely affected by ketosis. Treatment with intravenous

glucose or adrenal cortical hormones is quite effective, but some cows are resistant to therapy. Oral administration by stomach tube or drench of sodium propionate or propylene glycol for a period of time after calving is quite effective in preventing ketosis. However, this is inconvenient and not widely used.

Grass tetany, a disorder characterized by a low blood magnesium level, sometimes occurs when cows are placed on lush pasture. Grass tetany is not as common in dairy cattle as in beef cattle, largely because of different management and feeding systems characteristically used with the two cattle types. Grass tetany can usually be prevented by supplementing the ration with magnesium in areas where grass tetany is common. Treatment consists of intravenous injection of a magnesium gluconate solution.

The above and other metabolic disorders affecting dairy cattle are discussed in more detail in NRP 20420.

Parasite problems in dairy cattle. (See NRP 20420 and NRP 20480) Numerous external parasites are troublesome to dairy cattle. Dairymen are more concerned about losses due to flies than those due to other external parasites. The face fly and the horn fly are pests only of pastured cattle, whereas the stable fly may be found on both pastured cattle and on cattle in confined feeding operations. All these species may interfere with normal grazing and feeding activities, and, therefore, cause reductions in milk production and/or weight gains. In addition, the face fly is known to be involved in the spread of pink-eye, a problem that is reaching epidemic proportions as the populations of this species are rapidly increasing. It has been shown that when face fly populations increase to more than 30 flies per face, the incidence of pink-eye may be 50 percent or greater. Another fly pest which may not cause measurable losses to the animals directly, but which must be controlled for sanitary reasons is the house fly.

Problems in the control of these fly pests are numerous. Most of the fly control procedures used today involve the use of insecticides to control adult flies by either applying the insecticides directly on the animals or in barns as residual treatments or space sprays. The insecticides used for these treatments are for the most part the same as those used 10 years ago since the pesticide industry is registering less new compounds because of costs involved in obtaining registrations for new compounds.

These methods of control have several disadvantages. First, they are expensive and generally have a short duration of effectiveness. Secondly, there is a great deal of labor required to apply the insecticides. Pastured cattle are particularly difficult to treat effectively, especially for face fly control. Thirdly, most species of flies are becoming resistant to most insecticides and it is only a matter of time until this problem becomes acute.

Additional information on current technology for fly pests and for other external parasites of cattle can be found in NRP 20480. Information on internal parasites of cattle can be found in NRP 20420.

B Visualized Technology

Reduce mastitis in dairy cows - Appropriate research will permit the development of new techniques and knowledge that will make it possible to reduce the incidence, severity, and duration of infection, and to avoid the sale of abnormal milk associated with mastitis. These objectives can be attained through a broad research approach involving prevention and control by identifying (1) herd management factors, (2) milking machine characteristics, (3) methodology of detecting diseased quarters, (4) methods of assessing and augmenting natural defense mechanisms, (5) improved procedures for treating infections, (6) essential components of a successful quality control program, and (7) genetic variations in resistance.

Improvements in technology will have an effect on problems related to mastitis by reducing the new infection rate, by shortening the duration of infection and by decreasing the proportion of the milk and meat supply contaminated with antibiotics or other mastitis-related abnormalities.

Reduce new infection rate - Whereas the current new infection rate is 10 infections per 100 cows per month, improved technology is expected to reduce the rate to two per 100 cows per month. Part of the improvement will be accomplished by developing resistance through breeding. Specific physiological and anatomical features through which genetic variation is expressed, will be identified. This will permit selection for specific traits known to reduce mastitis incidence. Likewise, information will be available on the relationship between selection for high milk production and mastitis incidence. Methods will be developed to collect incidence data through production testing plans and this information will contribute greatly to the pool of genetic information. Advanced technology available within 10 years will provide for more effective preventive means. New management techniques and improved milking and sanitation practices will help prevent mastitis. Further studies of dry cow therapy will show conclusively whether treatment of all dry quarters has any preventive efficacy. Optimum products for such therapy and application strategy will be known. Milking machines will be available with improved characteristics which will reduce udder stress and the risk of transmitting disease pathogens. Physiological defense mechanisms to intramammary infections such as phagocytosis and the immune system will be identified.

Reduce duration and effects of intramammary infections - The duration of infection will be reduced from the current 10 weeks to two weeks as a result of improved technology. New technology will establish whether increased natural resistance is also accompanied by more rapid recuperation from infection. An important development will be that of practical inexpensive and accurate field procedures for the detection of diseased quarters. Perhaps pathogens can be identified during the milking act by devices added to the milking machine. New and improved mastitis screening tests will be developed and the use of these tests as an effective tool in the National Cooperative Dairy Herd Improvement Program will be expanded and refined. Improved therapeutic measures will permit development of treatment strategies aimed at specific pathogens. Additional anti-microbial therapeutic products will be developed. Attention to physiological defense mechanisms will be responsible for developing techniques and/or non-antibiotic agents to augment basic defense mechanisms and to shorten the duration of infections. The improvements in technology related to reducing new infections and shortening the duration and severity of infections will reduce milk production losses from the current 5 percent to 2 percent of the total milk supply. The cost of therapeutic drugs will be reduced from $6.00 per cow per year to $2.00 per cow per year and the loss due to early calving from 2.5 percent per year to 0.25 percent per year.

Decrease contamination of milk and meat - It is expected that losses due to unmarketable milk will decrease from 0.5 percent to 0.2 percent of the total supply. Improved quality of bulk tank milk will result from clarifying the cause-effect relationship between somatic cell count and abnormal milk. Research will be responsible for the development of logical quality control strategies based on successively lower tolerance limits for acceptable cell counts. An improved understanding of the relation between antibiotic use in intra-mammary therapy and possible subsequent tissue residues will be developed. Possible contamination of the milk supply with various sanitation compounds will be understood.

Decrease incidence of metabolic disorders - Improved technology will reduce the incidence of milk fever by providing simple inexpensive but completely effective methods of prevention. Materials for treatment will prevent relapses. Herd owners will be able to identify cows likely to develop milk fever. Management factors which may be conducive to or tend to prevent milk fever will be known. Rapid diagnosis of ketosis will be possible and feeding and management practices preventing its occurrence will be available. More effective materials for treatment will be developed. Methods of assuring adequate magnesium intake and cows grazing on tetany-prone pastures will substantially reduce the incidence of grass tetany.

Decrease incidence of other diseases and disorders and reduce losses from toxic materials - Visualized technology resulting from research on other diseases and disorders and on toxic materials is presented in NRP 20420 and 20470.

Reduce parasite problems - (See NRP 20480 and 20420) The overriding objective will be to develop methods of controlling flies more effectively, using less organophosphorus insecticides for adult fly control. Methods to be investigated include control of flies in immature stages (as larvae or pupae) as well as methods to control adult flies. Control measures for immature stages of the horn fly and face fly would consist of using effective feed additives for the control of these pests of pastured cattle. Research would include finding effective materials as well as developing methods and formulations for feeding the compounds. Research on the use of insect growth regulators as feed additives for fly control should include studies on the problems of resistance and how these might be able to be overcome. Although control of flies in immature stages where they are not pests is the method of choice, it is realized that adult fly control measures will also be necessary. With implementation of the visualized technology and the resulting reduced fly populations, it is not unlikely that the reduction in loss of milk due to horn, stable, and face flies could be up to 50 percent. Major reductions in face fly populations that could be accomplished could reduce the cases of pink-eye significantly so that it becomes a less serious problem of pastured cattle.

C Research Approaches

Only mastitis is included under this heading. Other research approaches to mastitis control can be found under NRP 20420. Research approaches to the control of other dairy cattle diseases can be found under NRP 20420 and to external parasite control under NRP 20480.

Both basic and applied research are required to determine modes of transmission of the several microbial agents causing bovine mastitis, as well as to determine those environmental, physiological and anatomical factors which influence resistance and susceptibility in the host. A complete research program should include investigations in herd management, milking practices and equipment, microbiology, physiology, immunology, pathology, and genetics. These disciplines must be pursued jointly and simultaneously to develop a full understanding of the disease complex and to achieve effective experimental designs. The research approaches are outlined according to epidemiological strategy.

1 Reduce the mastitis infection rate

a Develop resistance to mastitis through breeding

(1) Identify the best quantitative measure of resistance to mastitis. (NER, Beltsville, MD)

(2) Determine heritability of the alternative measures of mastitis incidence. (NER, Beltsville, MD)

(3) Determine the anatomical structures or physiological defense mechanisms through which individual animal differences in resistance are expressed. (NER, Beltsville, MD)

(4) Study anatomical or physiological differences measurable in young or uninfected animals which are indicative of resistance to infection. (NER, Beltsville, Md)

(5) Study the genetic relationships between resistance to infection and other economic traits such as milk yield. (NER, Beltsville, MD)

(6) Determine if selection based on an index including mastitis resistance is feasible and economically desirable. (None)

b Develop measures which will prevent mastitis.

(1) Study various facets of herd management, milking practices, and sanitation.

(a) Identify the chief environmental reservoirs for the microbial pathogens. (None)

(b) Reveal the means other than by machine, by which the several pathogens gain entrance into the udder. (NER, Belts. MD)

(c) Determine sanitation practices which are effective in breaking the chain of transmission of pathogens. (NER, Belts. MD; SR, Lewisburg, TN)

(d) Study the cost-effectiveness of alternative sanitation regimes. (None)

(e) Identify environmental conditions relating to cow handling and housing which influence the rate and severity of udder infection. (NER, Beltsville, MD)

(f) Develop an economically optimum strategy for culling cows based on mastitis status and history. (None)

(2) Examine the effectiveness and economics of dry cow therapy.

(a) Determine if application of dry cow treatment to uninfected quarters confers any prophylactic value. (NER, Belts. MD)

(b) Study alternatives to antibiotics for prophylaxis in the dry period. (None)

(3) Examine milking machine characteristics which may be related to mammary gland infection. (None)

(a) Study characteristics of milking machines which may lead to the transmission of pathogens from the environment to the cow, from cow-to-cow, and from quarter-to-quarter within cows. (NER, Beltsville, MD)

(b) Study methods of evaluating the stress imposed on the udder by the milking machine. (NER, Beltsville, MD)

(c) Find if changes in design of milking machines will reduce udder stress, avoid impairment of natural defenses, and reduce risk of transmission of mastitis. (NER, Beltsville, MD)

(d) Study the inter-relationship of machine design and milking practices, as related to risk of udder infection. (NER, Beltsville, MD)

(e) Find some of the physiological parameters of the teat and udder which are affected by various milking machine characteristics. (NER, Beltsville, MD)

(f) Determine if automation of sanitation can be incorporated into machine design. (NER, Beltsville, MD)

(4) Elucidate mechanisms for physiological defense against mastitis.

(a) Determine if the immune system can be modified or augmented to increase resistance to mastitis pathogens. (NER, Beltsville, MD)

(b) Identify biochemical or enzymatic changes in mammary tissue which accompany the establishment of infection. (None)

(c) Study the role of the leukocyte in the mammary gland in promoting resistance to mastitis organisms. (NER, Belts. MD)

(d) Determine factors which affect the ability of the leukocyte to destroy organisms within the gland. (NER, Belts. MD)

(e) Establish which nutritional factors affect the cow's defenses against mastitis. (None)

(f) Determine other physiological factors, such as hormones, involved in resistance. (None)

(g) Determine why the non-lactating gland is so susceptible to new infection. (None)

2 Eliminate established mastitis infections

a Increase recovery rate through breeding.

(1) Find if natural resistance to mastitis is also characterized by ability to recover from an infection more rapidly. (None)

b Develop more rapid and accurate methods of detecting diseased quarters.

(1) Find methods of detecting mammary gland infection by specific organisms on the farm. (None)

(2) Study applicability of alternative screening tests for cell concentration to routine use in production testing. (NER, Beltsville, MD)

(3) Determine best use by dairymen of screening test results in individual cows.

(4) Study efficacy of bacteriological screening through DHIA.

(5) Identify biochemical or enzymatic changes in the udder which accompany infection and determine if these changes can be used for mastitis detection.

(6) Determine most practical and feasible method of detecting S. agalactiae infected herds.

c Develop more satisfactory therapeutic measures for treating mastitis.

(1) Study the optimum strategy and products for dry cow treatment.

(2) Develop methods of aiming therapy more directly at actual organisms involved.

(3) Determine if agents which alter the natural defenses of the animal can be used for more effective treatment.

(4) Find factors which prevent therapeutic agents from being as effective *in vivo* as *in vitro*.

(5) Determine if different treatment procedures should be used for open or pregnant cows or during estrus.

3 Prevent abnormal milk and meat from entering market channels.

a Develop improved quality control methods for bulk-tank milk.

(1) Study the relation between somatic cell count and abnormal milk.

(2) Determine best screening tests for detecting abnormal milk from individual cows.

b Study means of preventing tissue residues following mastitis therapy.

(1) Identify gaps in knowledge of suitable withdrawal periods for various therapeutic products.

c Reduce milk contamination with sanitizing compounds.

(1) Find if automated application of teat dip compounds adds to risk of chemical contamination of milk. (NER, Beltsville, MD)

(2) Identify sanitation compounds which may be more apt to constitute contamination problems than others. (NER, Beltsville, MD; SR, Lewisburg, TN)

D Consequences of Visualized Technology

1 Reduce the farm cost of milk production.

2 Improve quality of milk and meat.

3 Reduce and make more specific the widespread use of antibiotics and other drugs presently used in treating mastitis.

4 Reduce the frequency of dairymen being excluded from the market due to excessive cell counts or contaminated milk due to mastitis.

5 Improve food safety and reduce health hazards to man and farm animals.

6 Provide knowledge that will contribute to a better understanding of resistance of animals to infection.

7 Contribute technology that will lead to reduced losses from mastitis in beef cows, sheep, swine and dairy goats.

8 Contribute technology that will have worldwide application among lactating animals.

9 Reduce cost of preventive measures by introducing them into the milking equipment system.

10 Possible decrease in rate of genetic improvement in milk yield if selection for mastitis resistance is introduced, depending on the genetic correlation.

E Potential Benefit

Dairy production practices have important effects on losses due to diseases, pests and other hazards but since potential benefits have been calculated in other NRP's, no statistics are shown or are benefit values listed in this NRP. This is done in order to avoid duplication.

Benefits are indicated for advancements in the control of various cattle diseases in NRP 20420, Control of Cattle Diseases. Those of particular interest to the dairy industry are as follows:

Disease	Page Number
Mastitis	55
Calf scours and enteric diseases	9
Respiratory diseases	15
Foot rot	18
Metabolic diseases	51
Internal parasites	87
Toxicities	59
Coccidiosis	41

In addition, potential benefits from research on external parasites are shown in NRP 20480.

F Research Effort[1]

Current Support[2]

	RPA[3]	Year	SY's	Gross $ X 000	Expanded Support (ARS Only)
ARS	210	1975	9.6	705	
	211	1975	30.4	4,485	
	(Mastitis) (BARC) (NADC)	1975	(3.9)		5.9
	212	1975	7.2	750	
	213	1975	4.2	388	
	214	1975	--	--	
	Total-ARS	1975	51.4	6,328	5.9
SAES	210	1975	8.4	225	
	211	1975	34.6	2,955	
	212	1975	4.2	294	

213	1975	1.4	191
214	1975	3.3	214
Total-SAES	1975	46.9	3,879
Others	Not available		
Total ARS & SAES	1975	98.3	10,207

Years required for ARS
and related SAES to
achieve Visualized Technology 10

[1]Statistics recorded here are specifically for dairy cattle and included in and are a part of statistics shown in NRP 20420, 20460, 20470 and 20480.

[2]From the Inventory of Agricultural Research, FY 1975, Vol. I, CSRS, USDA, March 1976

[3]Abbreviated titles of RPA's are as follows: 210 (Insects and External Parasites); 211 (Diseases); 212 (Internal Parasites); 213 (Toxic Chemicals and Poisonous Plants); 214 (Harmful Effects of Pollution)

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Concur T. B. Kinney Jr. — 10/29/76
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Note: The expanded support level reflected in this National Research Program represents staffs' views as to the additional level of staffing that can be effectively used in meeting the long-term visualized objectives for this program. These do not reflect commitments on the part of the Agency.

APPENDIX

References, Assumptions and Procedures Used in Estimating Potential Benefits of Dairy Production Research

A. References

1. Hoglund, C. R. 1975. The U. S. Dairy Industry Today and Tomorrow. Michigan State University Agricultural Experiment Station Research Report 275. May 1975. 19 pp

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4. Culver, D. W. 1973. 1985 Agricultural Directions. The Farm Index, April 1973. p 7-19.

5. Anonymous. 1975. Milk Facts. Milk Industry Foundation, Washington, D. C. 29 pp.

6. Anonymous. 1975. Dairy Producer Highlights. National Milk Producers Federation, Washington, D. C. 39 pp.

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9. Anonymous. 1975. Inventory of Agricultural Research FY 1974. Cooperative State Research Service, USDA. Vol. I. II, III.

10. Anonymous. 1975. Research to Meet U. S. and World Food Needs. Report of a Working Conference sponsored by the Agricultural Research Policy Advisory Committee. Kansas City, Mo., July 9-11, 1975. Vol I, II.

11. Anonymous. 1975. Dairy-Forage Research and Research Facilities. A National Review, The Current Situation, Recommendations for the Future. A Report to the National Planning Committee, NAULGC and USDA. February 1975 53 pp.

B. Assumptions and Calculations

1. General

In preparing statistics for the Potential Benefits Section of each Technological Objective (TO) numerous calculations were necessary. The calculations were made by several highly competent scientists. It is very difficult to predict the transference of research progress into technological achievements. Many assumptions were made and these assumptions appear to be reasonable but could be challenged.

In general, the base year for calculation was 1974 since statistics for that year were the last firm figures available. Thus, cow numbers, milk production, production per cow, cows bred artificially, feed costs, etc, are based on the calendar year 1974. Projections, when used, are based on information in papers by Hoglund (1) and Culver (4).

2. Specific by Technological Objectives

a. Improve efficiency of reproduction (III.1)

Calculations showing the estimated potential benefits by 1985 to the industry and the consumers by increased reproductive performance of dairy cattle are as follows:

(1) Reduce the cost of milk production by reducing the calving interval -

- 115 billion pounds milk in 1974 produced by 11.2 million cows averaging 10,286 pounds each

- Calving intervals estimated to be at least 13.5 months in 1974. Cost of maintaining cows in delayed breeding status, expressed as loss in milk production, is 60¢/day for each day of delayed breeding beyond 86 days after freshening and up to 116 days, and 94¢/day beyond 86 days where conception was delayed for 117 days or longer.

- Therefore, average cost is estimated at 78¢/cow/day beyond a 12-month calving interval.

- 13.5 - 12.0 = 1.5 months or 45 days delayed breeding or delayed breeding equivalent.

- If interval is reduced by 15 days, 11.5 million cows x 78¢ x 15 days = <u>$135 million potential annual saving due to reduced calving interval</u>.[1]

(2) <u>Reduce the loss of sterile cows</u>

- 12.6 million cows and heifers 2 years old and over in 1974.

- 5 percent sterility rate.

- 12.6 x 5 percent = 630,000 sterile females (without improved technology)

- 12.6 x 2 percent = 252,000 sterile females (with improved technology)

- Cost to raise dairy cow to 3 years = $500; salvage value = $350.

- 378,000 x $150 = <u>$57 million potential annual benefit</u>.

(3) <u>Reduce the loss of calves born dead and calves not born</u>

- 12.6 million females 2 years old and over.

- Estimated 5 percent calves born dead and 95 percent or 12.0 million will have calves.

- Therefore, 12.0 million x 5 percent = 600,000 born dead and 12,600,000 x 5 percent = 630,000 million not born in 1985.

- Also, with delayed breeding, only 0.9 calves born/cow are born per year

- This results in a loss of 12.0 x 0.1, or 1,200,000 calves.

- Value of calf lost will be $35.

- Therefore, (600,000 + 630,000 + 1,200,000 x $35 = <u>$85,000,000 potential annual benefit</u>.

[1] Cost component relates to cost of maintaining a cow in late stages of lactation when daily yield is low and during an unnecessarily long dry period.

(4) Reduce the cost of repeat breedings in artificial breeding

- Estimated cost to farmers for each repeat breeding is $4/service. 7.3 million cows bred by AI (artificial insemination) in 1974. Estimate 10 million cows to be bred by AI in 1985. By reducing services/conception rate from 2.0 to 1.5, 5 million services avoided.

- Therefore, 5 million x $ = $20 million potential annual benefit.

(5) Control of sex

- Sex control will permit breeding the poorest half of cows to beef bulls to produce males for market.

- 12.0 million cows to calve in 1985.

- Added value of crossbred males is $15 each.

- Desired sex ratio partially achieved 50-50 to 65-35 (30% achievement by 1985)

- Therefore, $\frac{12.0}{2}$ x 39% x $15 = $30 million potential annual benefits.

- Savings in making matings to produce AI bulls will also be made.

(6) Reduce the loss of bulls from artificial insemination centers due to infertility.

- 7.3 million cows bred by AI in 1974.

- 2,000 bulls in AI today, each servicing 3,650 cows/year.

- Estimate 10 million cows bred by AI in 1985, requiring 2,500 bulls, each servicing 4,000 cows.

- 7 percent of AI bulls/year lost because of infertility. 3 percent loss with improved technology.

- Therefore, 2,500 x 8 percent = 175 bulls/year will be lost in 1985. 2,500 x 3 percent = 75.

- This loss represents mature bulls which have been progeny tested and proven to be genetically superior.

- Estimated cost to purchase or mate, rear, progeny test and evaluate the 100 low fertility bulls is $10,000 per bull.

- Therefore, 100 bulls x $10,000 = $1 million loss avoidance or potential annual benefit.

(7) Increase average annual milk production per cow by 250 lbs. with improved understanding of milk synthesis.

- Presently 11.2 million cows producing 115 billion pounds of milk per year.

- At 10,536 lbs per cow only 10,915,000 cows would be needed to produce 115 billion pounds.

- 285,000 fewer cows required x $650 (cost of feeding and maintaining a cow for a year) = $185,250,000 million potential annual benefit.

(8) Reduce age for culling females for low production from 30 to 18 months.

- 11.2 million cows. 30 percent culled annually, or 3.36 million. 27 percent of these for low production or 907,000. If culled at 18 months rather than 30 months, there would be a saving of 12 months or one year per animal.

- 907,000 x 1 x $400 (estimated average annual cost of feeding and maintaining dairy heifers from 18 months to 30 months of age) = $363 million potential annual benefit. 25 percent implementation of the goal = $91 million.

(9) Reduce by two years the length of time bulls must be kept before they can be evaluated on the basis of their daughters' performance.

- Estimate 2,500 bulls needed for AI by 1985. If culling rate based on transmitting ability for production is assumed to be 20 percent, then 625 bulls culled out of 3,125 to provide 2,500.

- Gain from not using bulls of low transmitting ability much greater.

b. Improve efficiency of feed utilization (III.2)

Total Potential Benefits

The following prices and relationships have been assumed in estimating Potential Benefits as shown in III.2 E, Page 27.

- At present, nutrients for feeding dairy cattle are 60 percent forage and 40 percent concentrates. Cost/ton of TDN from forage is $120.00. Therefore, cost/lb of TDN from forage is $0.06.

- Cost/ton of TDN from concentrates is $180.00

- Therefore, cost/lb. of TDN for concentrates is $0.09.

- Feed cost/100 lbs. of milk is $3.55.

- Feed cost/100 lbs. of milk (above maintenance) $2.38.

(1) Increase the digestibility of energy from forages fed to dairy cattle by 10 percent or from 50 percent to 55 percent.

- Present farm value of hay and silage per ton on a hay equivalent basis = $50.00.

- $60.00 x 10 percent - $6.00 per ton increase in value

- Estimated cost of achieving improvement = $4.00

- 11.2 million cows x 4 tons x ($6.00 - $4.00) = $90 million potential annual benefit.[1]

(2) Replace one-quarter of the oilseed meal now fed with non-protein nitrogen and corn

- Estimate 5.6 million tons of oilseed meal required in 1985 on the basis of present practices.

- 100 lbs. of oilseed meal to be replaced by 14 lbs. urea and 100 lbs corn.

- Correspondeing values are $7.50 - (1.92 + 5.00) = $0.58 or $12 per ton saved.

- Therefore, $12 x 5.6 mil. tons/ 4 = $17 mil. potential annual benefit.

(3) Reduce losses in harvested forages from 25 to 15 percent.[2]

- Hay equivalent forage consumed by dairy cattle = 60 mil. ton.

- With present practices 80 mil. ton would be required to feed 60 mil. ton (80 x 75 percent = 60)

- If losses were reduced to 15 percent, 71 mil. tons produced would supply 60 mil. tons of feed.

[1] This benefit is considered as increased value of forages produced and will be essential to the attainment of Benefit D.

[2] This benefit is not considered as double counting with Benefits A and D because it is not dependent on increased digestibility or forage for concentrate substitutions.

- This would save 80 - 71 = 9 mil. tons of forage.

- Value of forage saved = 9 mil. x $50.00 = $450 mil.

- Cost of improved practices = $4 per ton x 71 mil. ton = $284 mil.

- Therefore, 450 - 284 = $166 mil. potential annual benefit.

(4) Substitution of forages for 7.5 percent of the TDN fed to dairy cows

- 7,160 lbs. of TDN required/cow/year.

- 7,160 x 7.5% = 537 lbs. in substitution.

- 537 x ($0.09 - $0.06) = $16 saved per cow less $5 for cost of production.

Therefore, $11 x 11.2 mil. cows = $123 mil. potential annual benefit.

(5) Increased digestibility of crop residues

- 125 mil. tons of residues would be available in 1985.

- Projected increase in value is ($40 - $25) x 125 mil. tons or $1,875 mil.

- Cost of processing is estimated at $10.00 x 125 mil. or $1,250 mil.

- Net benefit possible is $1,875 mil. - $1,250 mil. = $625 mil.

- About one-eighth this amount of material might be used by dry and growing dairy cattle thus, $625 ÷ 8 = $78 mil. potential benefit.

(6) Improved feed intake during early lactation

- Improve milk production by 250 lb/cow/year.

- Benefit per 100 lb. milk = milk price ($8.30/cwt) feed cost above maintenance (2.38/cwt. milk) - cost of application ($0.50/cwt.) = $4.42/cwt. milk

- Net benefit is $5.42 x 250 x 11.2 m = $152 mil. potential annual benefit

(7) Define requirements of all nutrients accurately

The results of correcting all nutritional imbalances cannot be well estimated since the extent of imbalance is not now known. It is likely, however, that the mortality, morbidity, and some of the antibiotic use associated with calf raising could be reduced by more refined nutritional knowledge. In the same way, metabolic diseases, such as ketosis and milk fever, should be reduced by improved nutritional balance. The waste due to over feeding some constituents should be eliminated and goals 2, 4 and 8 under C. Research Approaches (Page 24), would be more readily attainable with this type of information.

(8) Reduce losses in conversion of digested energy to milk from (50 percent to 40 percent)

- Reduce amount of feed required above maintenance by 20 percent.

- Reduce total amount of feed required by 10 percent.

- Cost of implementation = 7 percent of feed cost.

- Net gain = 3 percent of total cost = .03 x 3.55 = $.107/cwt. milk. $0.107/cwt x 115 billion lbs milk = $123 mil. potential annual benefit.

(9) Total potential benefits from TO III.2 quantitated

- $749 million annually

c. Improve genetic capacity for production (III.3)

Total Potential Benefits

Key to Abbreviations:

AI - Artificial Insemination
IOF - Income Over Feed Cost
PD - Predicted Difference

The following prices and assumptions have been made in estimating Potential Benefits as shown in III.3 E, page 37.

- Dairy cow population is 11.2 million. (1974)

- Milk price basis is 1974 price of $8.20 for 3.5% milk with an 8¢ fat differential: calculations based on 3.7% milk at $8.36/cwt.

- 6.6 million cows bred by AI bulls. (1974)

- 4.6 million cows bred by non-AI bulls. (1974)

- Based on research at milk price of $5.85, extra IOF in first lactation of daus. of AI bulls was $3.22/100 lbs. PD of sire.

- Extrapolated to present milk price (1974) of $8.36 = $4.60/100 lbs. PD.

- Assume dairymens' costs have risen faster than milk price so they receive only 80% of benefit from increased milk price: .80 x $(4.60 - 3.22) + $3.22 = $4.32/100 lbs. PD.

- Add 10% to extrapolate over all lactations: $4.32 + $.43 = $4.75 extra IOF/100 lbs. PD.

- Prior research indicates that because of heavier use of high PD bulls, effective PD is about 50% higher than average PD of active AI bulls.

- Average PD of non-AI bulls is 50% of effective PD of active AI bulls.

- There are 180,000 dairy farms with an average herd size of 60 cows. (1974)

- Average annual turnover rate is 30%

- Turnover rate can be decreased by 20%, from 30% per year to 24% per year.

- On the average cows will last 4.2 lactations instead of 3.3 lactations.

- It costs $400 to raise a calf from birth to first parturition (1974).

- Salvage value of a cow sold for beef is $300. (1974)

Calculation of Potential Benefits

(1) Improved selection for yield of milk and milk components

Calculation of extra annual income over feed cost from dairy cows in the U.S. from present rate of genetic improvement.

- In 1975, average PD for milk of active AI bulls is +425 lbs. making the average effective PD, 1.50 x 425 = 637 lbs.

- Extra IOF received by dairymen is:

  From the use of AI bulls - 637 lbs. PD x $4.75/cwt. PD x 6.6 mil cow = $200 mil.

From the use of Non-AI bulls - 637 lbs. PD/2 x $4.75/cwt
PD x 4.6 mil cows = $70 mil.

- Total extra IOF per year from present rate of genetic improvement for yield = $270 million.

Calculation of extra annual income over feed cost from dairy cows in the U.S. in 1985, assuming more accurate genetic evaluations and selection techniques through proposed research and the current dairy cow population of 11.2 million.

- Assume that in 10 years, through more accurate genetic evaluations and selection techniques, the average PD for milk of active AI bulls can be raised to +750 lbs. (effective PD = +1125 lbs.).

- Extra IOF received by dairymen would be (assuming a continued cow population of 11.2 million):

From the use of AI bulls - 1125 lbs. x $4.75/cwt PD
x 6.6 mil cows = $353 mil.

From the use of non-AI bulls - 1125 lbs/2 x $4.75/cwt
PD x 4.6 mil cows = $123 mil.

- Total anticipated extra IOF in 10 years = $476 million.

Increased annual benefits over present rate due to added genetic improvement in 10 years = $476 million - $270 million = $206 million.

Calculation of extra annual income over feed cost from dairy cows in 1985 assuming more accurate genetic evaluations and selection techniques through proposed research and a dairy cow population of 9 million.

- If it is assumed that the cow population decreases to 9 million in 10 years and the level of AI bull usage remains the same, the extra benefits would be:

Present total benefits remain the same at $270 million

Benefits from the use of AI bulls in 10 years remain the same at $353 million

Benefits from use of Non-AI bulls (on the 2.5 million cows remaining) decreases to - 1125 lbs/2 x $4.75/cwt
PD x 2.5 mil cows =
$67 million.

- Total anticipated extra IOF in 10 years = $420 million.

Increased annual benefits over present rate due to added genetic improvement in 10 years in a population of 9 million cows = $150 million.

Calculation of benefits from proposed research in a 60-cow herd.

- For an average size herd (60 cows) the added benefits would be:

  For herds using AI bulls:

  Present = 637 lbs. x $4.75/cwt PD x 60 cows = $1815
  In 10 years = 1125 lbs x $4.75/cwt PD x 60 cows = $3206
  Extra benefits = $3206-1815 = $1391 per herd

  For herds using non-AI bulls:

  Added benefits would be one-half or $695 per herd

Calculation of benefits from proposed research in a 100-cow herd.

- If it is assumed average herd size will increase to 100 cows in 10 years, additional benefits would be:

  For herds using AI bulls:

  Present = 637 lbs. x $4.75/cwt PD x 100 cows = $3026
  In 10 years - 1125 lbs x $4.75/cwt PD x 100 cows = $5344
  Extra benefits = $5344-3026 = $2318 per herd

  For herds using non-AI bulls, added benefits would be one-half of $1159 per herd.

(2) Improve methods of identifying and genetically evaluating economically important non-yield traits.

Calculation of benefits from reducing replacement rate in Nation's dairy herds from 30% to 24% (i.e. by 20%).

- A 30% turnover in a 60-cow herd is 18 cows per year at a cost of $100 per cow ($400-$300) = $1,800 annual replacement cost.

- a 24% turnover in a 60-cow herd is 14.4 cows per year at a cost of $100 per cow ($00-$300) = $1,440 annual replacement cost.

- The difference is a savings of $360 per herd per year.
- Full benefits to the 60% of herds using AI bulls = 180,000 herds x 60% x $360 savings = $38.9 million.

- One third benefits to the 40% of herds not using AI bulls = 180,000 herds x 40% x $360 savings x 1/3 benefits = $13 million.

- Benefits of lowered replacement costs = $51.9 million.

  One-half of benefits due to fulfillment of this objective = $26 million.

Calculation of benefits from reducing veterinary and medicine costs by $5 per cow/yr.

- Veterinary and medicine costs would be lowered an average of $5 per cow/yr.

- Full benefits to the 6.6 million cows resulting from AI breeding = $5/cow x 6.6 million cows = $33 million.

- One third benefit to the 4.6 million cows resulting from non-AI breeding = $5/cow x 1/3 x 4.6 million cows = $7.6 million.

- Benefit in lowered veterinary and medicine costs = $40 million

- One half of benefits due to fulfillment of this objective = $20 million.

Calculation of benefits from reducing losses of high-producing cows and subsequent increased opportunity for within-herd selection.

- Reduced losses of high producing cows and increased opportunity for within-herd selection will increase production 100 lbs. milk/cow.

- Full benefits to the 6.6 million cows resulting from AI breeding = 1 cwt milk x $8.20/cwt x 6.6 million cows = $54 million.

- One third benefit to the 4.6 million cows resulting from non-AI breeding = 1 cwt milk x 1/3 benefit x $8.20/cwt x 4.6 million cows = $12.4 million.

- Benefit in higher yield per cow = $66.4 million.

- One half of benefits due to fulfillment of this technical objective = $33.2 million.

(3) <u>Comments on benefits from improved statistical and computer technology</u>.

- Direct financial benefits are rather small in terms of dollars, but important to ARS in terms of lowered computer costs and manpower costs.

- Indirect benefits are considerable in terms of other research that could be accomplished by freed ARS resources and increased timeliness, accuracy, and availability of genetic information to industry.

(4) <u>Comments on benefits from increased recognition of genetic defects and recognition of adverse or ignored genetic effects</u>

- Potential benefits are difficult to quantify. Some of the miscellaneous genetic effects may have tremendous economic importance. For example, if present selection practices are not appreciably narrowing genetic base, then consequences are relatively unimportant. However, if we are seriously narrowing genetic base and face a loss of adaptive polymorphism if present practices continue, then it is a serious problem of potentially catastrophic proportions. An example of this is we may be breeding a population that is genetically dependent on large amounts of concentrates especially high protein feeds. The sudden unavailability of these feeds (due to weather or economics) could mean a drastic reduction in milk produced nationally and economic disaster for large "feedlot" type herds.

(5) <u>Total potential benefits TO III.3 quantitated - $229 mil.</u>

d. <u>Improve management practices and systems (III.4)</u>

(1) Benefits from improved dairy management systems

- Better feeding systems (Already covered in TO III.2)

- Herd management systems to detect cows in estrus (See III.1)

- Herd recordkeeping systems

  Increase production by 2.5 percent
  (115,000,000,000 lbs. x 5% x $8.20/cwt = $235,750,000

  Save 1 hour of labor per cow per year

  (11,200,000 cows x 1.0 hours x $2.00 per hour = $23,400,000)

- Optimum grouping programs should increase milk production by 1 percent.

  115,000,000,000 lbs x 1% x $8.20/cwt = $94,300,000

  Cost of production = 40,825,000

  Benefit $94,300,000 - $40,825,000 = $53,475,000

(2) Benefits from increased labor efficiency in dairy herd management.

- Reduce labor for feeding and bedding by 6.25 hours per cow per year. (11,200,000 cows x 6.25 hours x $2.00 per hour = $140,000,000)

- Reduce labor for miscellaneous chores by 2.5 hours per cow per year. (11,200,000 cows x 2.5 hours x $2.00 per hour = $ 56,000,000)

(3) Benefits from increased efficiency and effectiveness of milking systems.

- Reduce labor for milking by 6.25 hours per cow per year. (11,200,000 x 6.25 hours x $2.00 per hour = $140,000,000).

- Improve consumer acceptability of milk by 2 percent in 10 years. (See III.6)

- Reduce losses due to mastitis (see 6.1).

(4) Benefits from improved dairy cattle waste management.

- Benefit to mankind by reducing threat to health. (dollar value difficult to estimate)

- Benefit to mankind by reducing nuisance of offensive odors and improving work efficiency of residents of affected areas. (dollar value difficult to estimate)

- Use of milk processing wastes as animal feeds (See TO III.2)

- Use of animal wastes as fertilizer, feed and fuel. (dollar value difficult to estimate)

(5) Benefits from lower dairy herd replacement losses.

- Death loss of replacement heifers reduced by 7 percent. (11,200,000 cows x 80% calf crop x 50% heifer calves x 7% reduced calf loss x $50 per calf = $15,680,000)

- Reduced veterinary and medicine costs for treating sick calves. (11,200,000 cows x 80% calf crop x 50% heifer calves x $4 per calf savings = $17,920,000)

- Efficient growth of heifers with lower feed and labor costs. (Dollar value difficult to estimate)

- Replacement heifers ready to enter milking herd at one month younger age because of efficient growth. (4,000,000 replacements annually x $16.67 per heifer per month cost of raising = $66,680,000) (Cost of implementation $2.50/heifer/month = 10,000,000)

- Benefit = $56,680,000.

(6) Benefits from reducing effects of environmental stress

- Increase milk production in the South and Southwest through environmental control to overcome heat stress. (25,000,000,000 pounds of milk x 2.5 increase x $8.20/cwt = $51,250,000. (Cost of environmental control = $10 mil.)

- Benefit = $41,250,000

- Increase milk production in the cold northern parts of the U.S. through environmental control to reduce cold stress. (32,000,000,000 pounds milk x 1% increase x $8.20/cwt = $26,240,000) (Cost of environmental control = $5 mil).

- Benefit = $21,240,000

- Improve reproductive efficiency in both hot and cold climates. (dollar amounts difficult to estimate because exact losses to temperature stress are not known)

- Improve feed efficiency and rate of gain and reduce health problems in both hot and cold climates. (Dollar amounts difficult to estimate because exact losses are not known.)

e. Improve efficiency of producing quality products (III.5)

(1) Production of more milk protein

The calculations presented below indicate the possible benefits of research to increase the production of milk protein. However, these potential benefits are not claimed under TO III.5 of this NRP; instead, the benefits projected under NRP 20600 (Marketing Livestock and Animal Products) include those associated with increasing the amount and efficiency of production of milk protein. This will circumvent possible double accounting for economic gains from milk protein research.

(a) Current milk protein production and value

- 3758 mil. lbs. x $1.04/lb = $3,908 million

(b) Projected milk protein production by 1985

- 370 lb/cow/yr = 4,036 million lbs.
- 4036 million lbs x $1.04/lb = $4,197 million
- Increase of $289 million

(c) Subtract costs of implementing new technology, e.g. incorporating protein content into national performance testing and genetic improvement programs.

(d) Add benefits from increased efficiency

(e) Claim 25% of increased milk protein production as a benefit. Therefore, $289 million x 25% = $72 mil.

(2) Increase the suitability and acceptability of milk for various uses

Development of new knowledge and associated technology would have potential to decrease waste milk and increase the acceptability of market milk to the consumers. It is possible that such work, if successful, might mitigate the projected decrease in per capita consumption. However, no benefits are claimed from such developments.

(3) Improve the flavor and odor of milk

Date are not available to quantify present losses and potential benefits in this area.

(4) Reduce the proportion of milk produced that fails to meet accepted legal standards.

Data are not available to quantify present losses and potential benefits in this area.

f. Decrease losses due to diseases, pests and other hazards (TO III.6)

No benefits due to mastitis control advances are claimed under TO III.6 for the production research NRP (20350). Mastitis research is also conducted under NRP 20420 (Disease Control - Cattle). In order to prevent any possible duplications in claims for improvements due to research, all benefits for mastitis are included under NRP 20420.

However, in order to illustrate those developments which might accrue from mastitis research conducted under production

research NRP 20350, calculations are presented below for the technology visualized to be achieved by 1985. The production losses and other costs of mastitis can best be documented in terms of the listed economic specifications. The farm value of milk was estimated at $9.7 billion in 1974, in addition to approximately $2.2 billion from the sale of beef and veal and from dairy animals. In this industry, the potential benefits by 1985 from reduction in mastitis is estimated as follows:

(1) Milk production not realized due to mastitis

- Production in 1973 was 115,620 million lbs milk x 11.6 million cows, or an average of 9,967 lbs/cow.

- Production required in 1985 will be 120 billion lbs. milk.

- If current 5% loss in production is reduced to 2%, production per cow would increase from 11,000 lbs. to .98 x (11,000 lbs. divided by .95) = 11,347 lbs./cow.

- Therefore, 120 billion lbs. divided by 11,347 lbs per cow = 10.575 million cows required to achieve desired milk supply, or 335,000 less than with current technology.

- 335,000 cows x $650 (cost of feeding and maintaining a cow for a year) = $217.8 million potential annual benefit.

(2) Milk voluntarily discarded (abnormal due to mastitis related problems).

- Production required in 1985 will be 120,000 million pounds. With existing technology, it is estimated that 1% is discarded: .01 x 120,000 million lbs. = 1,200 million lbs. discarded.

- If discard rate is reduced to .2% in 1985, .002 x 120,000 million lbs. = 240 million lbs. discarded.

- Therefore, 1200 million lbs - 240 million lbs = 960 million lbs. of milk will be saved annually by 1985.

- At current cost of milk production of an estimated $6/cwt. x 916 million cwt. = $57.6 million potential annual bneefit. (This benefit could be estimated as $56.7 million, if computed on the basis of 87,300 fewer cows required).

(3) Cost of therapeutic drugs and veterinary services

- At current estimated treatment costs/cow/year, the cost to the dairy industry in 1985 would be 10.91 mil. cows x $6 = $65.5 million.

- If the visualized technology were achieved completely, the cost would be reduced to 10,575 million cows (assuming benefit 1 is achieved) x $ or 21.2 mil. thus accomplishing $65.5 million - $21.2 million or $44.3 million potential annual

(4) Loss due to early culling or death of cows

- According to the specifications developed for current technology in 1985, there would be a need for 10.91 million cows of which 2.5% will be culled/year because of mastitis.

- The culling cost per cow is estimated at $500 (cost of raising cow) minus $300 salvage value = $200 net per cow.

- Thus, with current technology, the annual cost to the industry in 1985 will be 10.91 million cows x 0.025 x $200 = $54.6 million.

- If the visualized technology were achieved completely, including benefit 1, the cost of early culling would be reduced to 10.575 million cows x .0025 x $200 = $5.3 million, thus accomplishing $54.6 million - $5.3 million or $59.3 million potential annual benefit.

(5) Potential losses from the market for infractions of abnormal milk control regulations.

- Milk production required in 1985 has been estimated at 120,000 million lbs.

- If .5% of the total supply is wasted because of exclusion of dairymen from market, .005 x 120,000 million lbs = 600 million lbs. of milk lost in 1985 with existing technology.

- If this were reduced to .1%, .001 x 120,000 million lbs. = 120 million lbs. lost by 1985.

- Therefore, 600 million lbs. - 120 million lbs. = 480 mil. lbs. milk saved at the current cost of milk production of $6 per cow, 4.8 million cwt x $6 = $28.8 million potential annual benefit.